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First steps towards a TCM-based music therapy

Vegetative Functions Induced by Music

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Dissertação de Candidatura ao grau de Mestre em Medicina Tradicional Chinesa submetida ao Instituto de Ciências Biomédicas Abel Salazar da Universidade do Porto

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Abstract

Introduction

Music is an emotional language (Juslin and Sloboda 2011) and emotions induced by Music carry most of its therapeutic effects through the autonomous nervous system (ANS) (Ellis and Thayer 2010, Hodges 2010).

Heart rate variability (HRV) is a measure of the continuous interplay between sympathetic and parasympathetic influences on heart rate (HR) that yields information about autonomic flexibility and is highly connected to emotions (Cervellin and Lippi 2011). Individuals with greater emotion regulation ability have greater levels of resting HRV (Appelhans and Luecken 2006, Thayer and Lane 2009).

Previous studies suggest that the relaxant baroque musical auditory stimulation immediately reduces the overall HRV (Roque et al. 2013) and that music therapy intervention is associated with a long-term increase of HRV (Chuang et al. 2011).

Traditional Chinese Medicine (TCM) is a system of findings and sensations designed to establish the functional vegetative state of the body (Greten 2007). We allocated different music pieces to vegetative functions as described by classic diagnostic criteria of TCM according to their potential emotional and vegetative effects.

Objectives

- To compare the effect of different music pieces on HRV.
- To allocate different excerpts of musical pieces to the phases of TCM and the emotional movements as described in the vectorial model of balance according to its features.
- To create a source of data on the psychophysical response.

Methodology

The present experiment is a descriptive study about the effects of Music on HRV. The inclusion criterion was: adults aged 18 to 65 years. The exclusion criteria were cardiac and psychiatric chronic disease, treatment with chronotropic drugs and being a professional musician.

A Portuguese population validated questionnaire about individual differences relative to emotions was applied (Trait Meta-Mood Scale 24) in order to assess attention to emotion, clarity of feeling and mood repair. The volunteers' heart rate (HR) was collected consistently in the seated position, in rest conditions, during three minutes. Then, the auditory stimulation consisted of seven musical excerpts of ~60 seconds duration played on a random order, with ~15 seconds of interval in between and simultaneous collection of HR and respiratory rate (RR).

HR was collected with Polar H7 pre-cordial device and the following HRV parameters were calculated through CardioMood App: HRV Ti (triangular index), SDNN (standard-deviation normal-to-normal), RMSSD (root mean square of the successive differences) and LF/HF (low-frequency/high frequency), the first three are time-domain methods of calculating the HRV and the last one is a sympathetic indicator.

Results

46 participants were recruited; one male participant was excluded due to heart block. The sample consists of 45 individuals, 15 males and 30 females, with a medium and median age of 35 and 33 years old, respectively.

General findings**:** Basal HRVTi decreased per year of age with statistical significance as known from the literature.

A small non-significant correlation between TMMS-24 emotional repair score and HRVTi was verified in the younger participants (≤35 years old) (8%). Anyway, TMMS-24 repair score was not dependent of age, sex or basal HRV. This is compatible with prior findings of a correlation between regulatory features of emotionality and HRV.

Musical observations: It is known that relaxant baroque music may decrease HRV. Also in our study HRVTi and SDNN decreased significantly. However we could identify a special piece with high impact (Bach's *Weihnachts-Oratorium*) and a piece with relative low impact (Wagner's *Die Walküre).* This is compatible with the vectorial model mentioned above, as the first piece is regarded as calming and mediating sensations of security, whereas the second is regarded as stimulant (iratic).

LF/HF ratio, a sympathetic indicator, tendentiously decreased in most music pieces, but only significantly in Grieg's *Morning Mood*. Faure's *Pavane* almost reached significance. However, a stimulant piece (Mascagni's *intermezzo)* of voluptive features associated with a slight increase of this ratio and Wagner's *Die Walküre* had the smallest decrease.

We couldn't find significant differences in the overall sample of n=45 when comparing the HRV effects with the values of the previous music or with the basal values.

Discussion

The emotional repair score had a small non-significantly correlation with HRV basal values. Basing on TCM, we suggest that greater levels of HRV allow a better emotional regulation, because the person is more "flexible" to respond to different stimuli.

The decrease of HRV values during music auditory stimulation was verified also in other studies. Different music pieces decreased HRV on a different level, and Bach *Weihnachts-Oratorium* reached the highest immediate decrease of HRV. Some authors have stated that Bach's velocity is too high to autonomously adapt, our data do not support this thesis.

The meaning of the HRV values in the context of music is not clear in regards to “healthy” or “unhealthy” reactions. Our work hypothesis is that music induces changes in HRV, in sympathetic or parasympathetic tonus, which we interpret as an emotional reaction in the person; therefore, we suggest the development of an interpretation based on a matrix according to the vectorial emotion model of TCM in the future.

Comparing Grieg and Mozart, two musical pieces in a major tone and similar tempo (60 bpm), we check that only Grieg’s *Morning* decreased LF/HF almost to the half. This significant decrease in LF/HF ratio is compatible with the hypothesis that Grieg’ *Morning* may acts as an Earth vector, which is emotionally sedating and vegetatively downregulating in the sense of TCM.

Conclusion

1. According to our understanding of TCM and the emotional model of Damásio, the vegetative effects almost equal emotional effects.
2. According to the vectorial balance of emotions, individual differences of reactions to music could be explained. However, allocation of music effects to the emotional vectors still is a big challenge.
3. An emotional vectorial assessment model may be suggested by combination of standard questionnaires assessing the individual balance of emotionality, consisting of all four emotional directions simultaneously. This may allow to better correlate emotional and vegetative effects of music.
4. A next step could be to determine individuals with strong changes in HRV to specific pieces of music and search for emotional features that they have in common (emotional vegetative resonance) on the way to precisely allocate music pieces to the needs of patients as a functional vegetative and emotional therapy.
5. Music has partly predictable vegetative effects and its application as therapy may in the future be based on its specific features and the emotional and functional state of the patient with predictable effects.

Key words: music, emotion, heart rate variability, vegetative, sympathetic, parasympathetic.

Resumo

Introdução

A música é uma linguagem emocional (Juslin and Sloboda 2011) e o sistema nervoso autónomo (SNA) parece ser a via através da qual as emoções induzidas pela música provocam a maioria dos seus efeitos terapêuticos (Ellis and Thayer 2010, Hodges 2010, Pereira 2013).

A variabilidade da frequência cardíaca (VFC) mede a interacção contínua entre os sistemas nervoso simpático e parassimpático, englobando informação acerca da flexibilidade vegetativa (Cervellin and Lippi 2011). Os indivíduos com maior capacidade de regulação emocional têm maiores níveis de VFC em repouso (Appelhans and Luecken 2006, Thayer and Lane 2009).

Alguns autores sugerem que música barroca relaxante provoque uma redução imediata na VFC (Roque et al. 2013) e que uma intervenção de musicoterapia se associe a um aumento da VFC a longo prazo (Chuang et al. 2011).

A Medicina Tradicional Chinesa (MTC) é um sistema de achados e sensações apurado para estabelecer o estado vegetativo funcional do corpo (Greten 2007). No presente estudo alocamos diferentes peças musicais a funções vegetativas, com base nos critérios de diagnóstico da MTC e de acordo com o seu potencial emocional e efeitos vegetativos.

Objectivos

- Comparar o efeito de diferentes peças musicais na VFC.
- Alocar diferentes excertos de peças musicais às fases da MTC e movimentos emocionais descritos no modelo vectorial de equilíbrio, de acordo com as suas características.
- Criar uma fonte de dados de resposta psicofisiológica.

Metodologia

O presente trabalho é um estudo descritivo dos efeitos da música na VFC. Critérios de inclusão: adultos com idade entre 18 e 65 anos. Critérios de exclusão: doença cardíaca e psiquiátrica, tratamento com cronotrópicos e ser músico profissional.

Foi aplicado um questionário validado para a população portuguesa (Trait Meta-Mood Scale 24) relativo à atenção às emoções, clareza de sentimentos e reparação emocional. A frequência cardíaca (FC) foi recolhida consistentemente na posição sentada, em repouso, durante três minutos. Depois disso, a experiência auditiva consistiu na audição de sete excertos musicais de ~60 segundos de duração por ordem aleatória, com 15 segundos de intervalo entre os excertos musicais e recolha simultânea da FC e frequência respiratória.

A FC foi avaliada com o dispositivo pré-cordial Polar H7 e os seguintes parâmetros de VFC foram calculados com a aplicação CardioMood: HRVTi (índice triangular da VFC), SDNN (desvio-padrão de intervalos normais), RMSSD (raiz quadrada da média do quadrado das diferenças entre intervalos) e LF/HF (rácio de baixa frequência e alta frequência), sendo os três primeiros parâmetros de domínio temporal da VFC e o último um indicador simpático.

Resultados

Foram recrutados 46 participantes; um deles foi excluído por bloqueio cardíaco. A amostra consistiu em 45 indivíduos, 15 homens e 30 mulheres, com uma idade média de 35 anos (mediana 33).

Achados genéricos: A VFC basal diminuiu por ano de idade com significância estatística, o que está de acordo com a literatura.

Foi verificada uma correlação pequena e não significativa entre o score de reparação emocional da TMMS-24 e a VFC nos participantes mais jovens (≤35 anos) (8%). Contudo, este score não foi dependente da idade, sexo nem da VFC basal.

Observações relacionadas com música: Sabe-se que alguma música barroca pode diminuir a VFC. Também no nosso estudo os parâmetros relacionados com a VFC diminuíram significativamente. Contudo, identificámos uma peça com um impacto mais elevado (Oratória de Natal de Bach) e uma peça com menor impacto (Cavalgada das Valquírias de Wagner). Isto é compatível com o modelo vectorial mencionado, já que a primeira peça é conhecida como sendo calma e mediadora de sensações de segurança, enquanto a segunda é estimulante (irática).

O rácio LF/HF, um indicador simpático, diminuiu tendencialmente na maioria das peças musicais, mas apenas significativamente em Grieg. Na peça de Fauré esta diminuição quase que atingiu a significância. Contudo, uma peça estimulante com características voluptivas (Cavalaria Rusticana de Mascagni) associou-se a um ligeiro aumento deste rácio e a Cavalgada das Valquírias de Wagner teve o menor decréscimo.

Não foram encontradas diferenças significativas na análise dos dados relativos a toda a amostra aquando da comparação dos efeitos na VFC de uma determinada música com os efeitos verificados na música anterior ou com os valores basais.

Discussão

O score de reparação emocional correlacionou-se não significativamente com os valores basais de VFC. Com base na MTC, sugerimos que sejam os maiores níveis de VFC a permitir uma melhor regulação emocional, porque o indivíduo está mais flexível para responder a diferentes estímulos.

A diminuição da VFC durante a audição musical verificou-se também noutros estudos. Esta diminuição foi diferente em diferentes peças musicais e a Oratória de Natal de Bach associou-se à maior diminuição imediata da VFC. Alguns autores sugeriram que a velocidade de Bach poderia ser demasiado elevada para ocorrer adaptação vegetativa, mas os nossos dados não suportam esta tese.

O significado da diminuição imediata da VFC com música não é claro em termos de ser definido como "saudável" ou "não saudável". A nossa hipótese é que a música induza alterações na VFC, nos sistemas parassimpático e/ou simpático, que interpretamos como uma reacção emocional da pessoa; desse modo, sugerimos que no futuro seja desenvolvida uma matriz de acordo com o modelo vectorial da MTC para interpretar estes achados.

Comparando duas peças musicais em tonalidade maior e tempo semelhante (60 bpm), verificámos que apenas o excerto de Grieg diminuiu o indicador simpático para a metade, em relação ao concerto de Mozart. Esta diminuição do rácio LF/HF é compatível com a hipótese de que a peça de Grieg actue como um vector Terra, que é sedativo em termos emocionais e provoca regulação descendente em MTC.

Conclusão

1. De acordo com a nossa perspectiva da MTC e com o modelo de Damásio, os efeitos vegetativos aproximam-se dos emocionais.
2. Tendo em conta o equilíbrio vectorial das emoções, podem-se explicar diferenças individuais das reacções às músicas. Contudo, a alocação dos efeitos de músicas aos vectores emocionais ainda é um enorme desafio.
3. Através da combinação de questionários *standard* para avaliar o equilíbrio individual emocional de um indivíduo, pode ser desenvolvido um modelo vectorial de emocionalidade, que permita uma melhor correlação dos efeitos emocionais e vegetativos da música.
4. É importante determinar quais os indivíduos com reacções de VFC mais fortes em resposta a peças musicais específicas e investigar características emocionais que tenham em comum, com o intuito de prescrever peças musicais ao indivíduo como terapia vegetativa e emocional.
5. A música tem efeitos vegetativos parcialmente previsíveis e a sua aplicação como terapia no futuro pode ser baseada nas suas características específicas e no estado funcional e emocional da pessoa, com resultados previsíveis.

Palavras-chave: música, emoção, variabilidade da frequência cardíaca, vegetativo, simpático, parassimpático.

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Abbreviations

ANS	Autonomous Nervous System
bpm	Beats per minute
CAN	Central Autonomic Network
CNS	Central Nervous System
cpm	Cycles per minute
FFT	Fast Fourier transform
HR	Hear rate
HRV	Heart Rate Variability
HRVTi	Heart Rate Variability Triangular Index
Hz	Hertz
PNS	Parasympathetic Nervous System
RMSSD	Root mean square of standard deviation between adjacent N-N intervals
RR	Respiratory rate
RSA	Respiratory Sinus Arrhythmia
s	Second
SDNN	Standard deviation of all normal to normal intervals
SNS	Sympathetic Nervous System
TCM	Traditional Chinese Medicine
TMMS	Trait Meta-Mood Scale
TMMS-24	Trait Meta-Mode Scale 24

Introduction

Music and Emotion

Music is a language of the emotions (Cooke 1959), as it conveys emotion and influences listeners' emotions as well (Hunter and Schellenberg 2010). Studies using behavioral, psychological, physiological and neurological measurements indicate that listeners respond affectively to music (Mitterschiffthaler et al. 2007, Peretz and Coltheart 2003, Witvliet and Vrana 2007). Additionally, research suggests that people value music primarily because of the emotions it evokes, using music to change and release emotions, to match their current emotion, to enjoy or comfort themselves, and to relieve stress (Juslin and Laukka 2004, Sloboda and O'Neill 2001). Rather, some explanations suggest that we ascribe emotions to music because it sounds the way people sound when they are expressing particular emotions (Davies 2003 in Juslin and Sloboda 2011), or even that music sounds the way emotions themselves feel (Langer 1966 and Pratt 1952 in Juslin and Sloboda 2011).

Emotions are relatively intense affective responses, focused on specific objects (such as music) and lasting minutes to a few hours, that usually involve a number of sub-components – subjective feeling, physiological arousal, expression, action tendency, and regulation – which are more or less synchronized (Juslin and Västfjäll 2008). Evidence has been showing that music acts in all of these sub-components, which constitutes a combined evidence of music as an emotional language (Pereira 2013). It is interesting to note that moods are also affective states but with lower intensity than emotions, do not have a clear "object" and are much longer lasting than emotions (several hours to days); mood do not involve a synchronized response in components like expression and physiology. Feeling is the term used to refer to the subjective experience of emotions or moods; it is the one component of an emotion that is typically measured via verbal self-report (Juslin and Sloboda 2011).

The classical vision of emotion as mere evaluations of an object-relation (cognitive theory of emotion) has been considered to be insufficient and not pragmatic. The thesis that emotions originate from vegetative homeostasis, "within the body" is increasingly accepted.

Neurobiologically, emotions are complicated collections of chemical and neural responses, forming a pattern, that are individually shaped by a unique development and environment but also a result of a long history of evolutionary fine-tuning (Berntson et al. 2007, Damasio 2000, Damasio and Carvalho 2013).

Music is already used in a number of applications in society that presume its effectiveness in evoking emotions (soundtracks, marketing, music therapy). Musical emotions are emotions that were induced by music. But how can music features, *mere sound*, evoke emotions? They may be caused by brain stem reflexes, emotional contagion, visual imagery, episodic memory, musical expectancy and evaluative conditioning, which are the psychological mechanisms that can explain most emotions induced by music in everyday life (Juslin and Västfjäll 2008).

Theoretical and empirical research suggests that people generally agree on the basic emotion that a particular piece of music is expressing (Evans and Schubert 2008, Scherer 2004). Studies have also found musical characteristics such as tempo and mode that are correlated with particular expressed emotions (Juslin and Laukka 2004) (Schubert 2004) (Music features).

Perceived emotions are emotions represented by music and perceived as such by the listener. Perception of emotions is primarily a sensory or cognitive process that does not necessarily say anything about what the listener himself or herself is feeling, since perception of emotions may well proceed without any emotional involvement (Gabrielsson 2002). Evidence so far strongly suggests that while the emotions expressed in music are often the same as those felt, it is also possible for them to be different. Basically, people feel what music expresses but need not be always; in a simple case, only 61% of 45 participants felt what they perceived (Evans and Schubert 2008). The difference can be explained by neurological factors (Schubert 1996), physiological arousal (Dibben 2004), personality characteristics (Kallinen and Ravaja 2006), and autobiographical associations (Gabrielsson and Lindström 2001), although research is far from providing a single model that explains all of the reasons between the two emotion loci (perceived vs felt emotions).

The music and emotion research uses two main psychological models, focused on the perceived emotion: discrete and dimensional models (Juslin and Sloboda 2011). According to the well-known discrete emotion model – the basic emotion model – all emotions can be derived from a limited number of universal and innate basic emotions such as anger, disgust, happiness, sadness and fear (Ekman 1992). The universal patterns of emotionality are cross-cultural (Ekman and Scherer 1984). Instead of an independent neural system for every basic emotion, the two-dimensional circumflex model (Russell, 1980 in (Juslin and Sloboda 2011, Posner, Russell, and Peterson 2005) proposes that all affective states arise from two independent neurophysiological systems: one related to valence (a pleasure– displeasure continuum) and the other to arousal (activation–deactivation). In other words, all emotions, whether applied to music or the listener, can be understood as varying degrees of both valence and arousal. Russell's two dimensional valence/arousal model states its merit, within the ebb and flow of relevant woks, in the discipline of psychology (Wang and Huang 2014).

To study the relation of musical features to emotion, most psychological models focus on the perceived emotion. However, as previously noted, the perceived emotion need not be equal to the felt emotion and the felt emotion may not have the related physiological responses neither. Moreover, some patterns of the physiological responses appear while there is no related self-report (Evans and Schubert 2008). Since the perceived emotion, felt emotion, and physiological actions play different roles, a physiological model is necessary beyond the psychological models (Wang and Huang 2014).

The self-report methodology in the study of musical emotions has important limitations such as limited awareness of one's emotion and difficulties in the verbalization of musical emotions. Even though the subjective feeling is a main subcomponent of emotion itself, verbal reports of feeling are only approximations or circumscriptions of the inner experience of a listener and not direct mirror images of this experience (Juslin and Sloboda 2011). Music holds a power that goes beyond words. Because people cannot completely explain and translate what they emotionally feel, it is extremely important to measure physiological responses, investigating another main sub-component of emotion, the physiological arousal.

Extensive research in psychophysiology has demonstrated that autonomic and somatic processes are intimately associated with emotional responses (Juslin and Sloboda 2011, Larsen et al. 2008).

Emotional responses to music are undoubtedly at the core of why human beings value music so highly. Psychophysiological processes are an integral part of these emotional reactions. Nevertheless, clarifying the role that psychophysiology plays in musical emotions is fraught with numerous theoretical and methodological problems (Juslin and Sloboda 2011, Hodges 2010).

Emotion, ANS and HRV

The autonomous nervous system (ANS) is believed to be the way emotions induced by Music carry most of its therapeutic effects (Ellis and Thayer 2010, Hodges 2010) (Figure 1). Emotions themselves originate from the vegetative system.

The emotions that humans experience while interacting with their environment are associated with varying degrees of physiological arousal (Levenson 2003). A key system involved in the generation of this physiological arousal is the autonomic nervous system (ANS). The ANS is subdivided into an excitatory sympathetic nervous system (SNS) and an inhibitory parasympathetic nervous system (PNS) that often interact antagonistically to produce varying degrees of physiological arousal.

Emotion regulation depends critically on an individual's ability to adjust physiological arousal on a momentary basis (Gross 1998). A flexible ANS allows for rapid generation or modulation of physiological and emotional states in accordance with situational demands. In contrast, autonomic rigidity results in a lessened capacity to generate or alter physiological and emotional responses in synchrony with changes in the environment.

Heart rate variability (HRV) is a measure of the continuous interplay between sympathetic and parasympathetic influences on heart rate that yields information about autonomic flexibility and thereby represents the capacity for regulated emotional responding (Appelhans and Luecken 2006).

Although HRV is influenced by numerous physiological and environmental factors (for other factors, see Factors influencing HRV), two are particularly prominent and of psychophysiological importance: the influence of the ANS on heart and vasculature (Figure 2) and its regulation by the central autonomic network (CAN) (Appelhans and Luecken 2006, Makivić et al. 2013).

Considering the ANS anatomy on a peripheral level, the heart is innervated by the sympathetic and parasympathetic (vagal) branches of the ANS, which exert a regulatory influence on heart rate by influencing the activity of the primary pacemaker of the heart, the sinoatrial node (Vaseghi and Shivkumar 2008). Exploring the anatomy of ANS in more detail, the right and left vagus nerves innervate the sinoatrial (SA) and atrioventricular (AV) nodes, respectively; the atria are also innervated by vagal efferents, whereas the ventricular myocardium is sparsely innervated by vagal efferents. Sympathetic efferent nerves are present throughout the atria (including the conduction system), particularly in the SA node and ventricles (Makivić et al. 2013).

The two autonomic branches regulate the lengths of time between consecutive heartbeats (interbeat intervals or RR intervals in ECG recording); faster heart rates correspond to shorter interbeat intervals and vice versa. An increased heart rate could result from either increased sympathetic activity or decreased parasympathetic inhibition (vagal withdrawal) (Foteinou et al. 2011). The parasympathetic regulation of the heart is mediated by acetylcholine neurotransmission (through muscarinic receptors) and has a very short latency of response, with peak effect at about 0,5 seconds and return to baseline within one second. In contrast, sympathetic influence on heart rate is mediated by neurotransmission of catecholamines such as norepinephrine (through alpha and beta adrenoreceptors) and changes are slower, with peak effect observed after about four seconds and return to baseline after about 20 seconds (Pumprla et al. 2002 in Appelhans and Luecken 2006, Makivić et al. 2013). The autonomic control of the cardiovascular system is also affected by baroreceptors, chemoreceptors, muscle afferents, local tissue metabolism, and circulating hormone.

Attending to the difference in their latencies of action, the oscillations in heart rate produced by the two autonomic branches occur at different speeds, or frequencies (Appelhans and Luecken 2006, Makivić et al. 2013). This knowledge serves as the basis for the frequency-domain analysis of the HRV described below (HRV parameters), which describes high and low frequency rates of the variability changes.

Central autonomic network (CAN), also known as central command, is the integral component of an internal regulation system through which the brain controls visceromotor, neuroendocrine, pain, and behavioral responses essential for survival (Benarroch 1993 in Appelhans and Luecken 2006). The medulla is the primary site to regulate sympathetic and parasympathetic (vagal) outflow to the heart and blood vessels, specifically the *nucleus tractus solitarius* which receives sensory input and stimulates cardiovascular responses to emotion and physical stress (Makivić et al. 2013). Some neuroanatomical studies implicated inhibitory GABAergic pathways from the prefrontal cortex to the amygdala and additional inhibitory pathways between the amygdala and the sympathetic and parasympathetic medullary output neurons that modulate heart rate and thus heart rate variability (Thayer and Lane 2009).

The CAN supports regulated emotional responding by flexibly adjusting physiological arousal in accordance with changing situational demands. Thus, the CAN is critically involved in integrating physiological responses in the services of emotional expression, responding to environmental demands, goal-directed behavior, and homeostatic regulation (Appelhans and Luecken 2006). The neuroanatomical composition of the CAN includes cortical (medial prefrontal and insular cortices), limbic, and brainstem regions. The CAN receives input from visceral afferents regarding the physiological conditions inside the body and input from sensory processing areas in the brain regarding the external sensory environment (Benarroch 1993 in Appelhans and Luecken 2006). This input allows the CAN to dynamically adjust physiological arousal, including arousal associated with emotional expression and regulation, in response to changes in internal and external conditions. The output of the CAN is transmitted to the sinoatrial node (and many other organs), through the SNS and PNS branches described above, and directly influences heart rate. Therefore, HRV reflects the moment-to-moment output of the CAN and, by proxy, an individual's capacity to generate regulated physiological responses in the context of emotional expression (Thayer and Lane 2000, Thayer and Siegle 2002).

To sum up, there is a consistent physiological basis that supports the association between HRV and emotional regulation, through ANS.

Additionally, a growing body of evidence associates higher HRV with greater capacity for regulated emotional response, this is, the ability to generate emotional responses of appropriate timing and magnitude. In fact, there are studies relating greater HRV to the use of adaptive emotion regulation and coping strategies and reduced HRV with various outcomes indicative of emotional dysregulation, such as major depression (Agelink et al. 2002, Birkhofer, Schmidt, and Förstl 2005, Kemp et al. 2012). Some authors state low HRV as a risk factor for pathophysiology and psychopathology (Thayer and Lane 2009); others correlate poor HRV with adverse events and call HRV a tool able to assess autonomic imbalances and predict mortality (Thayer et al. 2012, Cardiology 1996).

In accordance to this, both research and theory support the utility of HRV as a noninvasive, objective index of the brain's ability to organize regulated emotional responses through the ANS and as a marker of individual differences in emotion regulatory capacity (Appelhans and Luecken 2006).

HRV parameters

The most commonly used HRV parameters in ANS evaluation are the **frequency-domain**, **time-domain**, and **Poincaré plot** parameters.

In which concerns the **frequency-domain** analysis, it is possible to distinguish the individual contributions of the sympathetic and parasympathetic systems by applying the frequency range differences in HRV analysis. Low-frequency (LF) modulation (0,04 - 0,15 Hz) of R-R interval changes corresponds to the sympathetic and parasympathetic activities together and is related to blood pressure regulation. High-frequency (HF) modulation (0,15 – 0,4 Hz) of R-R interval changes, that is, changes that occur rapidly, is primarily regulated through innervation of the heart through the parasympathetic (vagal) nerve and, logically, it is highly influenced by respiratory rate (Makivić et al. 2013).

LF/HF is the ratio of low and high-frequency powers after the fast Fourier transform and it is validated as a sympathetic activity indicator (Yanagihashi et al. 1997, Urakawa and Yokoyama 2005). Increased LF/HF values denote that the sympathetic nerve activity tended to be strong; thus LF/HF could be used as a physiological indicator of arousal levels (Wang and Huang 2014). Moreover, in conditions characterized by a shift of sympatho-vagal balance towards sympathetic predominance, the increase in the LF component of HRV was accompanied by a decrease in the HF component (both assessed in normalized units). The HF component of HRV is increased by controlled respiration, cold stimulation of the face, and rotational stimuli-all conditions that increase vagal activity (Malliani, Lombardi, and Pagani 1994).

The main **time-domain parameters** include both statistical and geometrical methods of analysis.

Within the statistical methods, there are of particular importance the standard deviation (SD) of all normal to normal (N-N) intervals (SDNN), that reflect the total variability and could be a good indicator of physiological valence (Geisler et al. 2010, Wang and Huang 2014); and the root mean square of SD between adjacent N-N intervals (RMSSD), also known as vagus-mediated HRV (Stein et al. 1994), that reflects parasympathetic activity (DeGiorgio et al. 2010). The N-N interval corresponds to the R-R interval of normal (sinus) beats, which excludes extrasystoles, for example.

It should be noted that the time-domain analysis is dependent on the length of recording period and, thus, in practice, it is inappropriate to compare SDNN measures obtained from recordings of different durations (Cardiology 1996).

Within the geometrical methods, HRV triangular index (HRVTi) measurement is the number of all NN intervals divided by the maximum of the density distribution and estimates of overall HRV. In practice, recordings of at least 20 minutes (but preferably 24 hours) should be used to ensure the correct performance of the geometric methods; that is, the current geometric methods are inappropriate to assess short-term changes in HRV (Cardiology 1996).

Being aware of their limitations, the following measures will be used for time domain HRV assessment: SDNN (estimate of overall HRV), HRV triangular index (estimate of overall HRV), and RMSSD (estimate of short-term components of HRV).

The third HRV parameter is represented by the **Poincaré plot**, which is a graphical representation of R-R intervals distribution and the cloud of points can be combined into an ellipse (CardioMood, 2014). A person’s R-R intervals are plotted over time and standard deviation is used to interpret changes seen in the plot. The standard descriptor 1 (SD1) represents the fast beat-to-beat variability in the R-R intervals, while the standard descriptor 2 (SD2) describes the longer-term variability (Makivić et al. 2013). The SD1 reflects mainly the parasympathetic input to the heart, while SD2 reflects both sympathetic and parasympathetic contributions to the heart (Makivić et al. 2013).

Factors influencing HRV

HRV is affected by factors such as respiratory patterns, age, body position, gender and, on a lesser extent, by lifestyle factors such as caffeine consumption (Parati and Di Rienzo 2003).

Respiration is well known to influence heart rhythm. Additionally, respiration is strongly linked to emotional responses and even musical preferences correlated with increases in respiration (Ries 1969).

Breathing air into the lungs temporarily gates off the influence of the parasympathetic influence on heart rate, producing a heart rate increase (Berntson et al. 1993 in Appelhans and Luecken 2006). Breathing air out of the lungs reinstates parasympathetic influence on heart rate, resulting in a heart rate decrease. This rhythmic oscillation in heart rate produced by respiration is called respiratory sinus arrhythmia (RSA), and was the first documented report of variability of cardiac rhythms, credited to Carl Ludwig in 1847 (Makivić et al. 2013).

Respiratory sinus arrhythmia is a phenomenon known to be entirely mediated by the PNS (Lewis et al, 2006), as only cardiac parasympathetic activity possesses a latency of action rapid enough to co-vary with respiration. In fact, a large majority of parasympathetically mediated variation in heart rate is produced by respiratory sinus arrhythmia (Berntson et al. 1997 in Appelhans and Luecken 2006), and some researchers have reported the magnitude of respiratory sinus arrhythmia as an index of parasympathetically mediated HRV (Grossman and Taylor 2007).

Respiratory rate is a powerful physiological stimulus with the capacity to alter several psychosomatic functions. Hyperventilation may associate with an immediate significant increase in HR during the first minute, a further small increase at 2nd minute of hyperventilation and a subsequent small decrease in HR at later portion of hyperventilation period (Deepak 2002).

In a simpler manner, the HRV increases when respiratory frequency decreases (Makivić et al. 2013). However, although respiration greatly affects the HRV, the absence of standardized models of respiratory frequency makes it difficult to interpret HRV data from that perspective (Makivić et al. 2013).

Age has a great impact on HRV too, much more significant than gender. Aging reduces the global measure of HRV (on both low frequency and high frequency domains) with older people tending to have lower HRV when compared to younger people (Zhang 2007). However, the time-domain short-term components of HRV (such as RMSSD) are not affected by age and, therefore, the fast vagal modulations of heart rate appear to be maintained (Reardon and Malik 1996).

Body position significantly influences cardiac autonomic drive in humans, considering that autonomic balance is clearly different between supine and vertical postures (standing or sitting). Sympathetic nervous function predominates in vertical postures, while vagal function predominates in recumbent postures (Watanabe, Reece, and Polus 2007).

It has been reported an increased in HRV in age-matched healthy volunteers after **caffeine consumption**, although this is not a consistent finding among other studies. Observations in healthy subjects are concordant with a transient and significant increase in vagal autonomic nerve activity measured by high frequency power analysis after the consumption of **caffeine** in a dose equivalent to two cups of coffee (Koenig et al. 2013, Notarius and Floras 2012).

Music and Cardiovascular Physiology

Musical auditory stimulation may synchronize intrinsic cardiovascular regularity, thereby modulating cardiovascular physiology (Bernardi et al. 2009).

Auditory music stimulation alters medium heart rate, although this is not a consistent finding among studies (Hodges 2010). HRV has a better performance evaluating the effects of music, as it is a physiologically grounded, theoretically explicated, empirically supported, computationally tractable measure of autonomic (dys)function (Ellis and Thayer 2010).

Some authors suggest that relaxant baroque musical auditory stimulation acutely reduces the overall HRV (Roque et al. 2013). Others investigated the effects of long-term, 8-month music therapy intervention on autonomic function in anthracycline-treated breast cancer patients and found a long-term increase of HRV (Chuang et al. 2011). Music therapy intervention is more than music auditory stimulation, as it is defined as a non-verbal psychotherapy (Benenzon 1988); it involves creating, singing, moving and listening to music within a therapeutic relationship (American Music Therapy Association, 2015).

Music features

Among factors affecting emotional expression in music, tempo and mode are considered the most important ones (Gagnon and Peretz 2003). Fast tempo may be associated with various expressions of activity/excitement, happiness/joy/pleasantness, potency, surprise, anger and fear. Slow tempo may be associated with various expressions of calmness/serenity, peace, sadness, solemnity, tenderness, longing, boredom and disgust. Then, differences between fast and slow tempo are mainly associated with difference in activation (fast tempo is generally associated with higher activation and slow tempo with lower activation). On the other hand, differences between major and minor mode are mainly associated with difference in valence (more positive in the case of major mode; more negative in the case of minor mode) (Juslin and Sloboda 2011). Music loudness (intensity), timbre, pitch, intervals, melody range, melody direction and motion, harmony, tonality, rhythm, articulation, amplitude envelope, pauses/rests, musical form are interesting less studied factors that influence many different emotional expressions of the music.

Our hypothesis is that Music can be used to influence vegetative function in a controlled way, if music's different features are taken into account. For this study, eight excerpts of non-vocal classical music pieces were selected, with different features (composer, style, andamento, tempo, mode, tonality, instrumentation) (Table 1).

The TCM perspective

Traditional Chinese Medicine (TCM) is a system of findings and sensations designed to establish the functional vegetative state of the body (Greten 2007).

TCM is based on yin and yang, although it is not reduced to these terms. Heidelberg model is a pragmatic reconstruction of TCM. Technical terms for yin and yang are used respectively such as depletion and repletion (functional capacity mostly induced by the vegetative system), algor and calor (microcirculation), intima and extima (neuro-immunological stages – *Algor Leadens Theory*) and yin and yang itself (structure *vs* function). The diagnosis, with its four components (constitution, agent, orb and Guiding Criteria), is fundamental in TCM (Figure 3). Therapeutical interventions are based on diagnosis.

Yin and Yang can describe regulation. Referring to the classical circle of yin and yang describing a circular movement, the phases Wood, Fire, Metal and Water can be inserted as parts of this regulatory model (Figure 4). The sinus wave of regulation is the projection of the circular movement (Figure 5). The target value (Earth), i.e. the centre of the movement, exerts a down-regulation in the first half of the movement and an up-regulation in the second half of it. This represents the overall vegetative activity of man: in yang phases sympathetic functions dominate more than in the yin phases; in yin phases the parasympathetic activity is relatively more present (Figure 6). Nevertheless, there are more than sympathetic and parasympathetic activities.

Phases are parts of a cyclic process, constitute cybernetic (regulatory) terms; referring to man, they are vegetative functional tendencies. The clinical manifestations of phases are called orbs. Wood is the phase of creating potential, understood as an amount of energy or the capacity of exerting work; it is a hypertonic phase (tense muscles, isometric exercises). Fire is the phase in which the potential is transformed to function or work; the patterns of motion tend to be hyperdynamic (ex.: moving hands while talking). Metal starts when the polarity of the sinus wave changes, i.e. when energetic relaxation occurs, such as *after a sigh*; then, there are a relative lack of energy. Metal is also responsible for the rhythmic control of body functions and of breathing. Water is the phase of regeneration of energetic potential. The Earth is the central turning point of the system and it’s a phase of transformation and evolution. Between Wood and Fire there is a change of direction and the force that initiates this is the Earth (Stomach orb). Between Metal and Water, there is also a change of direction which is initiated by the Earth as well (Lienal orb) (Figure 7).

An orb is defined as a clinical manifestation of a phase, named after a region of the body (body island); it is a group of diagnostically relevant signs, indicating the functional state of a body island (body region), which correlates with the functional properties of a conduit (Figure 8). 12 orbs were created, with two orbs per phase, except Fire that contained four orbs (two related with drive and the other two related with emotionality).

Although this diagnostically relevant signs may indicate dysregulation or disease, they are also part of the normal regulation. The sinus wave is adapted to the circadian rhythm of the day. The physiological movement of the sinus wave leads to normal adaptation of homeostasis over the day. Vegetative functions are the basis of specific behavior and orbs are basic neuro-emotional patterns (Figure 9).

It is interesting to note the mounting evidence appearing in the literature providing support to the hypothesis that ANS is involved not only in the regulation of viscera (heart, vessels, gastrointestinal tract, genitourinary system, etc.), but also in the modulation of immune system, inflammation, metabolism, suggesting a comprehensive role of general integration of ANS (Sternberg 2006 and Grassi et al. 2007 in Montano et al. 2009) that is highly compatible with western TCM-based models.

According to TCM, emotions originate from the vegetative system. Then, TCM is a vegetative medicine and also an emotional medicine.

Throughout History, many authors reinforced the ancient TCM findings that emotionality expresses the vegetative organ regulation. Aristoteles associated emotionality with an expression of organ functions. Darwin wrote about the development of emotion with other structures in man and animals on his 1872 book The expression of Emotions in Man and Animals (Darwin 1872). James-Lange 1890 theory's stated emotions as expressions of physical processes, and the perception of which as the basis of emotional experience (Lang 1994).

TCM's concept of emotions is even compatible with modern brain research. Damásio's insight that feelings are mental experiences of body states, which arise as the brain interprets emotions, themselves physical states arising from the body's responses to external stimuli (Damasio and Carvalho 2013).

The word **emotion** [e-motion] actually means *movement out of*. In TCM this can be taken literally: the vectorial inner motion is out of the well-balanced emotional state of the Centre. By the system of the phases (vegetative functional tendencies), a coordinate system of emotions can be formed; and emotions are, thus, a mixture of these moods and not one single mood alone. Putting it into a vector diagram makes easier to understand the balances of emotions that are sometimes contradictory and difficult to express in a western point of view. The representation of such *e*-motions consists in vectorial movements away from the target value (the center or balanced state) (Figure 10).

Emotions constitute a crucial component of the mechanisms of life regulation or homeostasis. And the functional homeostasis of emotions plays a core role in TCM, namely Heidelberg model. Anyway, TCM does not reduce people to their emotions.

There are four main inner motions: ira, voluptas, maeror and timor, each one of those representing a movement away from the target value (diagram), as mentioned above (Figure 10) (Greten 2007), which are often mistranslated by anger, joy, sadness and fear. **Ira** is the emotional aspect of wood phase (hepatic orb) and it consists of general vegetative and mental excitability/irritability. When it is compensated, initiative, autonomy, authority and ambition can occur. The emotional aspect of phase fire (cardiac orb) is **voluptas**, the tendency towards increased/excessive emotionality or increased emotional intensity. When compensated, people are joyful, creative, enthusiastic and communicative. **Maeror** is the emotional aspect of metal (pulmonary orb) and it is a tendency towards melancholy and depressiveness. When compensated, people are symbiotic, good teamer and receptive. **Timor** is the emotional aspect of water (renal orb) and it is defined as a feeling of latent threat and unconscious deep fear. People may be rational when compensated. **Cogitatio** is the emotional aspect earth phase (lienal orb) and it is the tendency to overthink or concerned thoughts up to excessive reflection. Compensated people can become reflective and contemplative.

All these emotional aspects of the internal orbs can become inner agents when decompensated. An agent is a pathogenic factor eliciting specific signs and symptoms, which may resemble and promote orb patterns. In this case, the agent is intrinsic to the individual. Ira can trigger choleric or aggressive behavior; voluptas may lead to egocentricity, manic-depressive and borderline behaviors. People with decompensated maeror may experience diminished self-esteem, over-sensibility or introversion. In timor, people can be rigid and compulsive when decompensated. In cogitatio, they think in roundabouts without end or solution.

Inner personality modes can be defined, as such the general (autonomy) in wood phase, the principal (emotionality/tempo) in fire phase, the minister (symbiosis) in metal phase, hinge and counterweight (rational control) in water phase (Greten 2007). In the same way, lifestyles as such life as an arena in wood, life on a stage in fire, life as in a sanatory in metal and life as in a castle in water (Greten 2007) (Figure 11). This knowledge reflects the influence emotions have in decision making and in actions themselves.

As previously referred, emotion is the component that comes out of actions; feeling is the component that comes out of our perspective on those actions. Curiously, it's also where the self emerges, and consciousness itself: mind begins at the level of feeling (Damasio 2012, 2003). *It's when you have a feeling that you begin to have a mind and a self*. This is highly compatible with Heidelberg perspective of the mental aspects of the phases (Figure 12). The body squeme is the perception of own physis and it starts to exist when the animated physis meets emotions, allowing inner self perception. Psycoalexia is the state when the person does not have access to his/her own body and own feelings.

Not surprisingly, emotion is integral to the processes of reasoning and decision making (Damasio 2003, Reis and Gray 2009): selective reduction of emotion is at least as prejudicial for rationality as excessive emotion.

There is a theory on TCM that stablishes a close network of thinking, acting and feeling, known as The Four-Layered Ontology (Figure 13) (Greten 2007). This theory is used in TCM psychotherapy and stablishes a relation between neuroanatomical structures and four kinds of intelligence, which evaluate life in a complementary way. The most primitive of these intelligences is the emotional or somatic intelligence, which is intrinsically related to the vegetative system. Then, the biological program intelligence is a relational intelligence and it is located in the limbic and paralimbic system; here, we have plots of behavior that are inborn and animalistic, in order to survive in the wilderness. Nowadays we live in the so-called civilized world, although uncivilized mechanisms come out of ourselves (Greten 2007). On a higher level, located in the frontal gyri of the forebrain, there is the rational-cognitive intelligence, which is a technical intelligence.

The inner self-knowledge is monitored by an instance which we call intuitive intelligence (Greten 2007); this intelligence gathers, monitors and commands all the other kinds of intelligence. It knows one's inner voice and why a decision was made; it also mediates between impulses of life and a person's own inner way, the *Dao* as TCM holds (Greten 2007).

Emotional or somatic intelligence comes from human's deepest feelings. TCM has the concept that emotions come from the body and the functional patterns of the body (Greten 2007). The goal of this kind of somatic or vegetative intelligence is that there is an inner feeling of balance. If this is not balanced, we see our surroundings from the standpoint of ira, maeror, voluptas or timor (Greten 2007). Then, the vegetative treatment, which is emotional treatment, may have a fundamental role in the holistic treatment of the person.

In fact, TCM concept of emotional-vegetative balance is extremely important. The power to re-establish the well-regulated state and the well-regulated state itself is named ***Orthopathy*** (Latin for “running straight”).

There are some strategies for the self-management of emotions in TCM. They include Qigong, a TCM form of mind/body exercise and meditation that uses slow and precise body movements with controlled breathing and mental focusing to improve balance, flexibility, muscle strength, and overall health (PubMed Health Glossary); ear acupuncture and Tuina (manual therapy techniques). Our question is: **why not music?**

Music and TCM

Music and TCM are connected in numerous ways. According to TCM, there is a theory that states that tonalities can allocate to the phases, i.e., following a sinus wave. Tonalities can even be related with the conduits. Also vowels have specific effects in the orbs, acting as therapy. And additionally vegetative auto-regulation achieved by Qigong can be used to improve musical performance.

We suggest that music may act through vegetative resonance phenomenon and/or by liberation of emotions. In the first, music may have a stronger effect on those individuals who have the musical expressed emotion in themselves by constitution or orb pattern. On the other hand, music may have the power to de-block emotions, expressing them instead of the own person (ex: iratic music in people with suppressed ira).

We allocated the different music pieces mentioned above (Table 1) to vegetative functions as described by classic diagnostic criteria of TCM according to their potential emotional and vegetative effects. This is the first hypothetic allocation of music pieces (Table 2; Figure 14), that needs to be confirmed through the creation of a source of data on the psychophysical response.

The present experiment is a descriptive study about the effects of Music on HRV.

The inclusion criterion was: adults aged 18 to 65 years (considering the effect of age on HRV). The exclusion criteria were: presence of cardiac chronic disease (such atrial fibrillation and other non-physiological arrhythmia, heart block), presence of chronic psychiatric disease (as major depression and schizophrenia), treatment with chronotropic drugs (like b-blockers and digoxin) and being a professional musician (the intimate contact should have chronic effects on HRV). The ingestion of caffeine beverages on a short time before the experiment was first considered as an exclusion criterion, but caffeine consumption is difficult to quantify accurately and, according to the literature, the caffeine average half-life is between four to seven hours; then, excluding the effects of caffeine in one's heart rate without blood sample analysis would be practically impossible.

The participants were evaluated on a single moment. The age, gender and past and/or present music experience were collected (also in number of years). Then, a Portuguese population validated questionnaire about individual differences relative to emotions was applied (Trait Meta-Mood Scale 24 – TMMS-24) in order to evaluate participants' emotional abilities. Specifically, the Trait Meta Mood Scale (TMMS) aims to assess relatively stable individual differences in people's tendency to attend to their moods and emotions (attention to emotions), discriminate clearly among them (clarity of feelings) and regulate them (mood repair). The TMMS-24 is the Portuguese modified version of the TMMS and was previously correlated to other mental health scales (Mental Health, Satisfaction With Life Scale, Ruminative Responses Scale, and Beck Depression Inventory) with the expected results; that is, emotional clarity and emotional repair were negatively associated with depression and rumination and positively correlated to satisfaction with life and mental health (de Figueiredo Queirós et al.). TMMS-24 is composed by 24 statements that should be rated by the participant from one (totally disagree) to five (totally agree) (Document 1); the first eight statements concern attention to feelings (ex: "I often think about my feelings"), the second eight statements concern clarity of feelings (ex: "I almost always know exactly how I am feeling") and the last eight statements concern emotional repair as the ability to regulate emotional states correctly (ex: "When I become upset I remind myself of all the pleasures in life").

After filling the questioner, the volunteers' heart rate was collected consistently in the seated position (because position is a strong determinant of vegetative regulation), in rest conditions, during a period of three minutes, which is enough to calculate the parameters in study.

Two non-invasive methods of collecting heart rate were applied: one largely used, commercially available and reliable precordial sensor (Polar H7) and a digital sensor developed in Faculdade de Engenharia of Universidade do Porto, with the purpose of validating the last one.

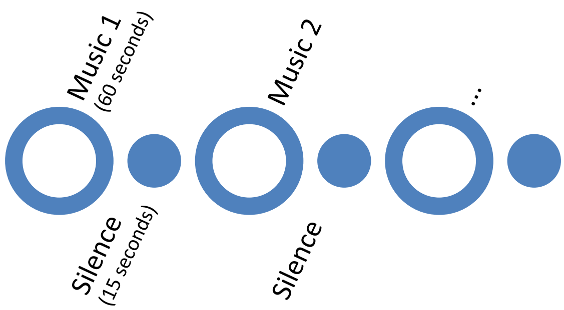
The external interferences were controlled with the minimization of sound and light distractions. Head phones were used to improve sound isolation conditions and personal comfort. After the initial basal HRV determination, the auditory stimulation consisted of seven musical excerpts of ~60 seconds duration played on a random order, with ~15 seconds of interval in between. As the same time as listening occurred, heart rate and respiratory rate were collected.

The musical excerpts were selected according to their different features (Table 1) and our first hypothetic allocation of music pieces based on the vectorial model of balance (Table 2). Only non-vocal music was used because of the influence of lyrics and language on music preference and understanding. The selected composers belong to different periods from the History of Music: J. S. Bach, Mozart, Handel, Grieg, P. Mascagni and Wagner. A random playing order was used to avoid the confounding effects brought by a fixed order. If the first piece of music played was always the same, it wouldn't be possible to know if the effect was because it was the first or because it was the specific music itself.

After the auditory stimulation period, the participants were asked if they knew the musical pieces that were played, if the music was pleasant and if they had memories of past life events when listening to it.

Considering the confounding effects of the circadian rhythm, the hour of collection of data was noted.

To sum up,



Results

A total of 46 individuals were recruited, 16 males and 30 females. One male participant was excluded because he had heart block, which affected severely the basal values in comparison to other participants; nevertheless, the data was collected with the purpose to assess the effect of music on his heart rhythm, with interesting results (Clinical case).

The sample consists of 45 participants, 15 males and 30 females, with medium and median age of 35 and 33 years, respectively (minimum 19; maximum 59). 23 individuals had past and/or present music experience, but only 13 of them had more than five-year musical experience. 22 participants were members of ICBAS TCM class (present or former students and teachers); the remaining participants didn't have a close link to TCM. The participants were evaluated during a wide but fixed time interval, considering the effects of the circadian rhythm: from 12 am to 10 pm.

General findings

The TMMS-24 was assessed to all but one non-fluently Portuguese speaking male participant.

The female group scored slightly higher on TMMS-24, mostly because of the attention to emotion and clarity of feeling scores. The male group had a younger medium age (Table 3). Nevertheless, TMMS-24 score was not dependent of age or sex (ordered logistic regression, $p>0,05$).

The TMMS-24 mood repair score of each individual was compared with HRV basal values (HRVTi, SDNN), in accordance to what literature states that individuals with greater emotion regulation ability have greater levels of resting HRV. A small non-significant correlation between emotional repair score and HRVTi was verified in the younger participants (≤35 years old) (8%) (Graphic 1). Anyway, TMMS-24 mood repair score was also not dependent of basal HRV (ordered logistic regression, $p>0,05$).

The effect of age on HRV was assessed and confirmed through HRVTi. Basal HRVTi decreased 0,23 units [-0,3072092; -0,1304085] per year of age with statistical significance (logistic regression, $p<0,05$) (Table 4, Table 5).

Musical observations

HRVTi and SDNN decreased significantly during music auditory stimulation (Table 6, Table 7, Graphic 2) in comparison to the previous basal values (Wilcoxon Signed Rank non parametric test, $p<0,05$). It should be noted that the difference between

HRVTi/SDNN during music and basal HRVTi/SDNN was higher in Bach's *Weihnachts-Oratorium* than any other music, especially Wagner's *Die Walküre*.

LF/HF ratio, a sympathetic indicator, tendentiously decreased in most music pieces, but only significantly in Grieg's Morning Mood (Wilcoxon Signed Rank non parametric test, $p<0,05$) (Table 8, Graphic 3). Faure's *Pavane* almost reached significance. On the other hand, Mascagni's *intermezzo* was associated with a slight increase of this ratio and Wagner's *Die Walküre* had the smaller decrease.

RMSSD represents vagus-mediated HRV, reflecting the amount of HRV that is attributable to parasympathetic system. In our sample, RMSSD decreased in all musical pieces but significantly in Grieg, Bach, Mozart and Handel. It did not decrease with significance in Fauré, Mascagni and Wagner, where it decreased only slightly (Table 9, Graphic 4).

The analysis of the difference between variables of HRV in relation to the previous music didn't come with different conclusions. We did not find significant differences in the overall sample when comparing the effects of LF/HF, SDNN and HRVTi with the values of the previous music or with the basal values.

Bach's Italian Concerto was a very small excerpt of 40 seconds that associated with much missing results: the software was not able to reliably calculate HRV in these situations, possibly because it would be very low. A minimum time of 50 seconds was required.

HRV was lower in those individuals who didn't know the music. The musical practice was not associated to an impact of HRV parameters during music auditory stimulation.

In what concerns the digital sensor developed to collect HR and then calculate HRV, sensitivity proved to be low on a continuous process of monitoring, with much data being lost, possibly because of involuntary movements, sweat or inability to collect the small capillaries pulse. Technical improvements in order to increase the sensitivity of digital sensors that could make them more reliable to make HR monitoring easier.

In what concerns respiratory rate (RR), the following results were found: RR was highest during Wagner *Die Walküre* and Handel Ombra Mai Fu. It was lowest during Fauré Pavane and Grieg Peer Gynt (Table 10). The quality of data was evaluated through the number of respiratory peaks detected, and only when the number of peaks was three or more it would be included for analysis.

General findings

The effect of age on HRV was evident in our sample. The literature states that older age is associated with lower HRV in comparison to younger age, and that was confirmed with significance through HRVTi values (and not with SDNN). In fact, although HRVTi measurement is not recommended for short time measurements, it proved to be more accurate in evaluating the basal HRV than SDNN.

The emotional repair score, and not the attention or the clarity score of TMMS-24, had a small non-significantly correlation with HRV basal values. That suggests that these two factors are somehow correlated: greater self-perception of emotional repair (as part of the process of emotional regulation) is associated with greater levels of HRV Ti, but there are others factors contributing to this correlation. In which direction is that correlation? Basing on TCM knowledge, we suggest that greater levels HRV allow a better emotional regulation, because the person is more “flexible” and able to respond to different challenges.

We could expect that the younger group, known to have increased basal values of HRV, would score higher on TMMS-24 emotional repair scale. That was not the case. We suggest that older adult people, through life experience and other non-vegetative mechanisms, can emotionally regulate better, despite their basal heart rate variability.

Emotional regulation abilities were, as expected, insufficiently evaluated through TMMS-24 mood repair score alone. We developed a diagram that suggests some of the scales that could be used to more accurately assess the emotional vegetative characterization of the person (Figure 15).

Musical observations

The decrease of HRV values during music listening doesn’t clearly mean that music decreases HRV, because of the different time period used in both moments (three minutes during basal HRV recording; about one minute each music piece) and the fact the two variables in study are time-domain (HRVTi and SDNN). Nevertheless, other studies found the same results and suggest that relaxant baroque music has the acute effect of lowering the HRV, although the long term effect could be of increasing HRV. Anyway, the HRV impact was greater during Bach’s *Weihnachts-Oratorium*. And relatively low during Wagner’s *Die Walküre*. This is compatible with the vectorial model mentioned above (Figure 14), as Bach’s *Weihnachts-Oratorium* is regarded as calming and mediating sensations of security, whereas the second is regarded as stimulant (iratic).

Basing on the fact that Bach's music induced a smaller synchronization with cardiovascular parameters when compared to other music pieces, some authors suggested that Bach's velocity was too high to autonomously adapt (Bernardi et al. 2009); our data do not support this thesis. The meaning of the HRV values in the context of music is not clear in regards to "healthy" or "unhealthy" reactions. Our work hypothesis is that music induces changes in HRV, in sympathetic or parasympathetic tonus, which we interpret as an emotional reaction in the person; therefore, we suggest the development of an interpretation based on a matrix according to the vectorial emotion model of TCM in the future.

Comparing Grieg and Mozart, two musical pieces in a major tone and similar tempo (60 bpm), we checked that Grieg decreased LF/HF almost to the half. This strengthens the value of the TCM allocation of music pieces on the diagram of the phases, once the significant decrease in LF/HF ratio is compatible with the hypothesis that Grieg' Morning may act as an Earth vector, which is emotionally sedating and vegetatively downregulating in the sense of TCM.

Mascagni's *intermezzo* associated with a slight increase of LF/HF ratio which is compatible with voluptive features of this musical piece (Figure 14). Wagner's *Die Walküre* had the smallest decrease of sympathetic values, possibly because of its iratic character.

The musical pieces composed by Grieg, Bach, Mozart and Handel significantly associated with a decrease of the HRV associated with parasympathetic system. Grieg musical piece also decreased the sympathetic indicator with significance, but not the other three. So, there were music pieces that affected more the parasympathetic than the sympathetic tonus.

RR rate was highest in opera styled music and lowest in music associated with less sympathetic activity. Some authors have questioned what would be the primary physiological alterations during music listening: does breathing causes ANS changes or is it the opposite? Some of the music pieces were respiratory moving, with the subjective feeling of increased rate and respiratory amplitude (Ombra Mai Fu, *for instance*), but it would be necessary to simultaneously analyze RR and HR to check whether which one of them changed first. Nevertheless, evidence points to the ANS as the main mediator of music's effects.

Clinical case

The excluded volunteer was also tested to document the effects music had on his HRV parameters.

This was a male participant, 59 years old, with numerous comorbidities, such as left bundle branch block, 1st degree auriculo-ventricular block, cardiac isquemic disease, hypertension, diabetes mellitus type 2 and alcohol abuse. The patient was medicated with bisoprolol 10 mg, telmisartan/amlodipine, clorotalidone 50 mg, spironolactone 25 mg, aspirin 150 mg, rosuvastatine, allopurinol 300 mg, victan 2 mg, metformine 850 mg, venlafaxine 37,5 mg, fluoxetine 20 mg.

This patient's basal values of HRV were altered in comparison to median values of the overall healthy participants, namely SDNN and RMSSD (Table 11), because of the enormous amplitude of HR values that he presented (Graphic 5). During the music auditory stimulation, a more restricted and controlled range of HR values was verified (Graphic 6). These are indicative findings, and we would need to use electrocardiography to document what happened in terms of heart rhythm.

Anyway, we assessed a clear decrease of HRV in this individual, mostly in Handel's musical piece (Graphic 6). This reinforces the study results that music immediately decreases HRV.

Limitations of the Study

Considering the limitations of this study, the methodological are the ones that highlight, because of the known difficulty that is studying the physiological effects of music.

At first, the time of music auditory stimulation should be the same as the initial assessment of basal HRV, in order to give the same amount of chances of variation during the same amount of time. Nevertheless, differences between music pieces checked in this time interval consistent in different subjects should mean different effects.

Secondly, we expect that the interval of 15 seconds between musical excerpts was sufficient to reach the basal value of HRV that patient had before, but this could not be determined with the present methodology. Ideally, it should be a period of evaluation of three or more minutes after the music listening of each musical excerpt to verify the effect immediately after music listening. Anyway, once we aimed to study the autonomous effects of music on vegetative system, which occurred almost automatically, a simultaneous collection of HR was performed. In order to don't lose the precedent effect, a variable of HRV parameters difference in relation to the previous music was considered.

Furthermore, statistical analysis means diluting individual patterns of response. There were individuals that did not respond to any music piece (non-reactors) and there were individuals that react more to a specific piece (Bach-reactors, Wagner-reactors …).

Future research

Given what was previously said about the individual patterns of music response, it would be interesting to determinate the individuals with strong changes in HRV to specific pieces of music and search for emotional features that they have in common.

For this purpose, to more accurately classify an individual in terms of vegetative functions and emotionality, a combination of standard questionnaires assessing the individual balance of emotionality (through the four emotional axis or directions) would play an important role (emotional vectorial assessment model).

Conclusions

According to our understanding of TCM and the emotional model of Damásio, the vegetative effects almost equal emotional effects. The suggestion that music has several therapeutic effects through music emotions and ANS is compatible and can be explained by these two perspectives.

Reaction to music differs from strength and apparently triggers different vegetative effects among the overall subjects. According to the vectorial balance of emotions, individual differences of reactions to music could be explained. Allocation of music effects to the emotional vectors still is a big challenge.

An emotional vectorial assessment model may be suggested by combination of standard questionnaires assessing the individual balance of emotionality, consisting of all four emotional directions simultaneously. This may allow to better correlate emotional and vegetative effects of music. In order to contribute to this purpose, we suggest other scales are important to more accurately assess self-perceived emotional regulation.

As referred, a next step could be to determine individuals with strong changes in HRV to specific pieces of music and search for emotional features that they have in common on the way to precisely allocate music pieces to the needs of patients as a functional vegetative and emotional therapy. For instance, it would be interesting to find whether the people who reacted more to Bach's *Weihnachts-Oratorium* had more anxiety related disorders (timor). By comparing all the subjects we can be diluting *clusters* of reactors to specific musical pieces that may share emotional similarities that may be inserted in TCM diagram of emotions.

Music has partly predictable vegetative effects and its application as therapy may in the future be based on its specific features and the emotional and functional state of the patient. Then, we suggest that the purpose of *prescribing* music is reasonable.

Music is probably associated with an immediate decrease of HRV. It is interesting to note that, although increased HRV is considered a marker of mental and physical wellbeing, HRV increases when there is the need of regulation. By *calming the heart*, music may decrease the need of regulation on the immediate. Nevertheless, on a long-term basis music could be associated with an increase of basal HRV, allowing a better emotional regulation in case of need.

Future research is also needed to establish if the relation of HRV to regulated emotional responding is dependent of other factors, such as intelligence or personality, on a western point of view, or such as constitution and TCM diagnosis.

We consider that this study served the purpose of gathering clues in the field of vegetative functions induced by music and it is still an early step in this stimulating area of investigation.

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Isaac Bashevis Singer

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Dedicada a todos os que apreciam música.

Sofia Sousa

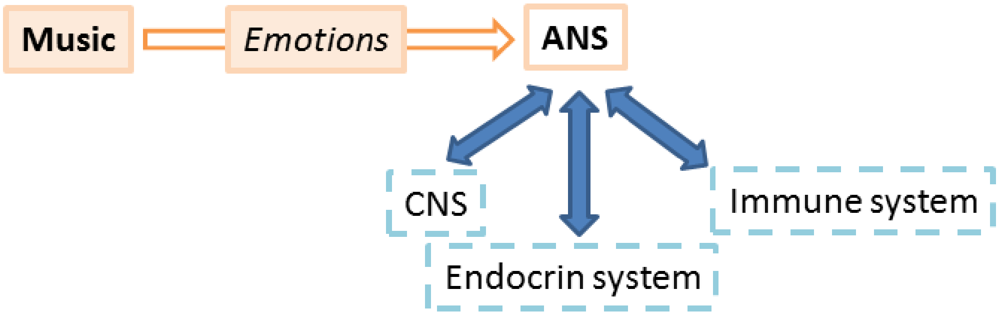


Figure 1: The therapeutic effects of music are autonomously mediated (Pereira 2013).

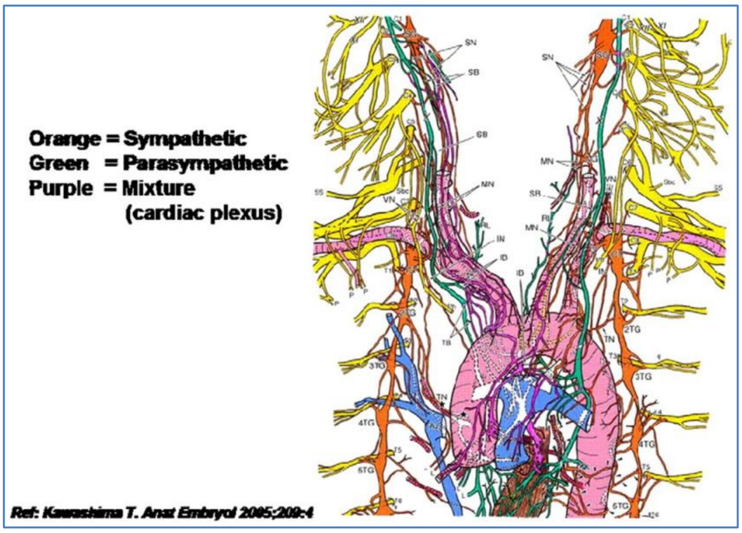


Figure 2: Autonomous Nervous System anatomy on heart and vasculature.

Table 1: Selected compositions and main features.

Composer	Style	Music piece	Andamento	Tempo (bpm)	Mode	Tonality	Instrumentation
R. Wagner	Romantic Opera	Die Walküre (1870)	Allegro	120	major	D major to B major	Orchestra
J. S. Bach	Baroque Concerto	1st movement of Italian concerto (1735)	Allegro	120	major	F major	Piano
Eduard H. Grieg	Romantic Suite	*Morning* from Peer Gynt Suite No.1 Op. 46 (1875)	Allegretto Pastorale	60	major	E major	Orchestra (Flute and Oboe)
Handel	Baroque Aria	Ombra mai fu (1738)	Largo	66	major	F major	Orchestra
Mozart	Classical Concerto	2nd movement Violin Concerto in G major K. 216 (1775)	Adagio	60	major	G major	Orchestra (Violin)
G. Faure	Romantic Pavane (slow processional dance)	Pavane Op. 50 (1887)	Andante molto moderato	72	minor	G minor	Orchestra
J. S. Bach	Baroque Oratorio	1st part of Christmas oratorio BWV 248 (1733)	Andante moderato	100	Major	D major	Orchestra
Pietro Mascagni	Romantic Opera	Intermezzo Cavalaria Rusticana (1890)	Andante sostenuto	76	Major	F major	Orchestra

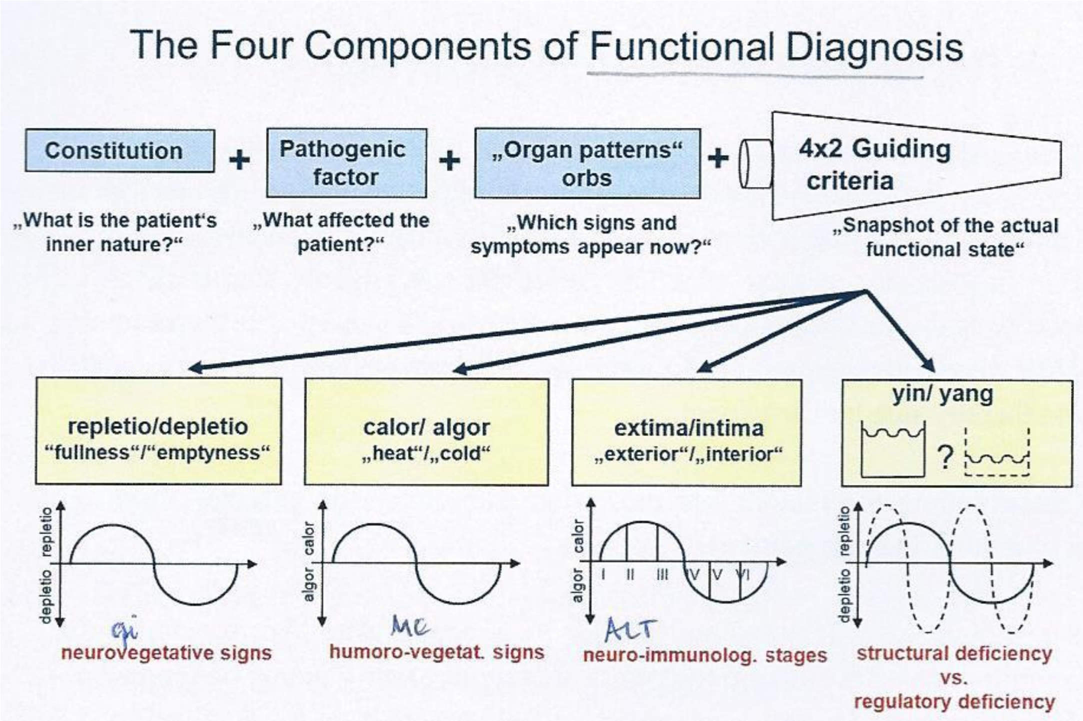
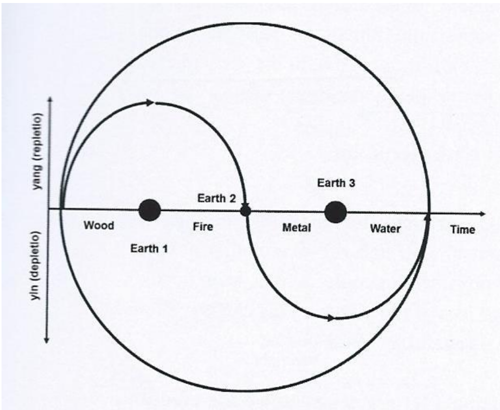


Figure 3: The Four Components of Functional Diagnosis: constitution, agent, orb pattern and guiding criteria (Greten, 2007).



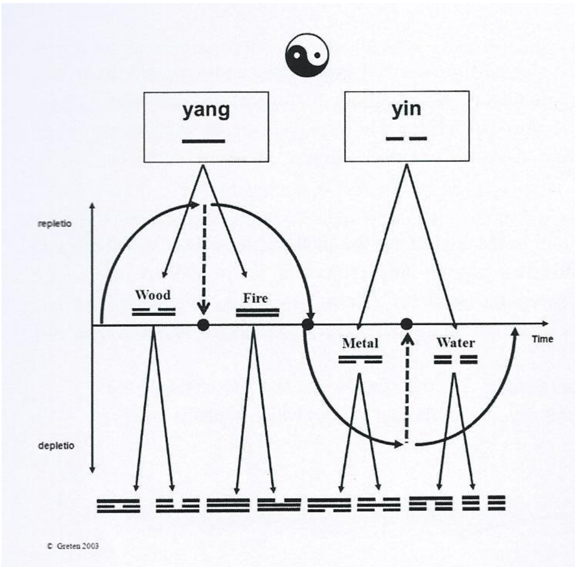


Figure 4: Yin and yang and the phases (Greten, 2007).

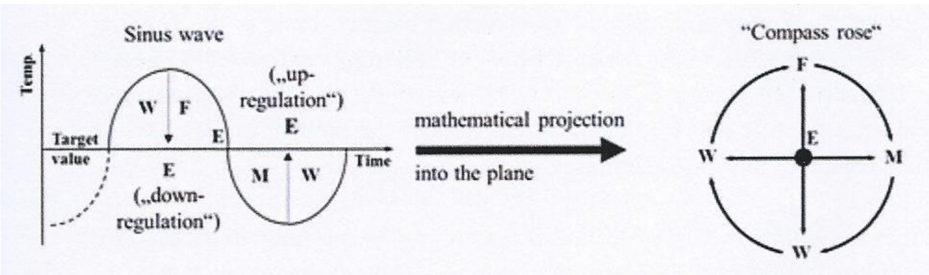


Figure 5: Sinus wave and compass rose – two perspectives of the same circular process (Greten, 2007).

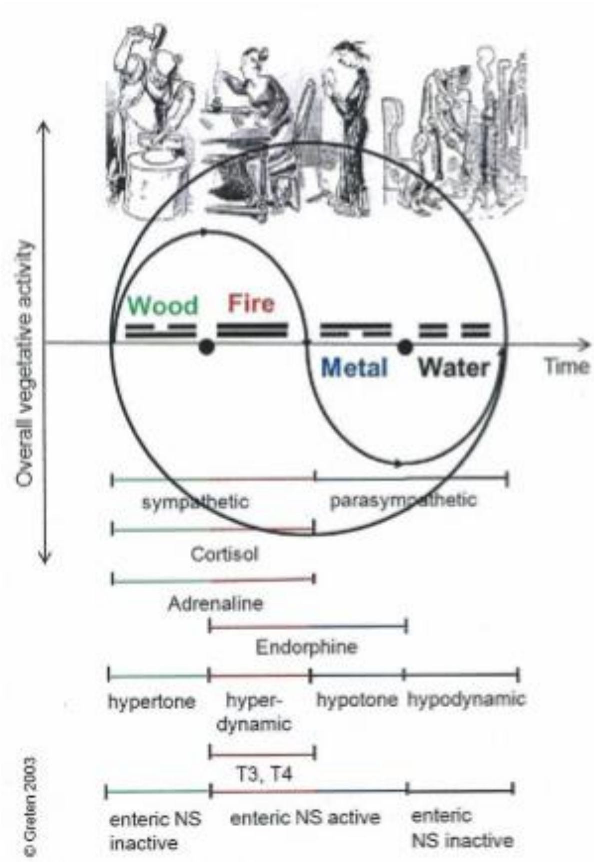


Figure 6: TCM and western concepts of the phases (Greten, 2007).

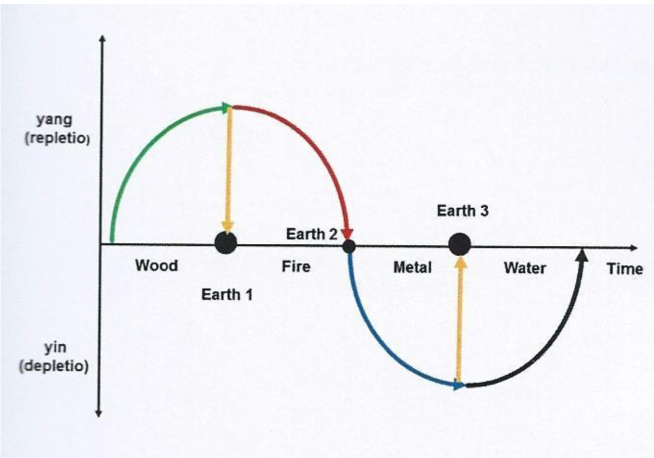


Figure 7: Vectorial represention of the phases on the sinus wave (Greten, 2007).

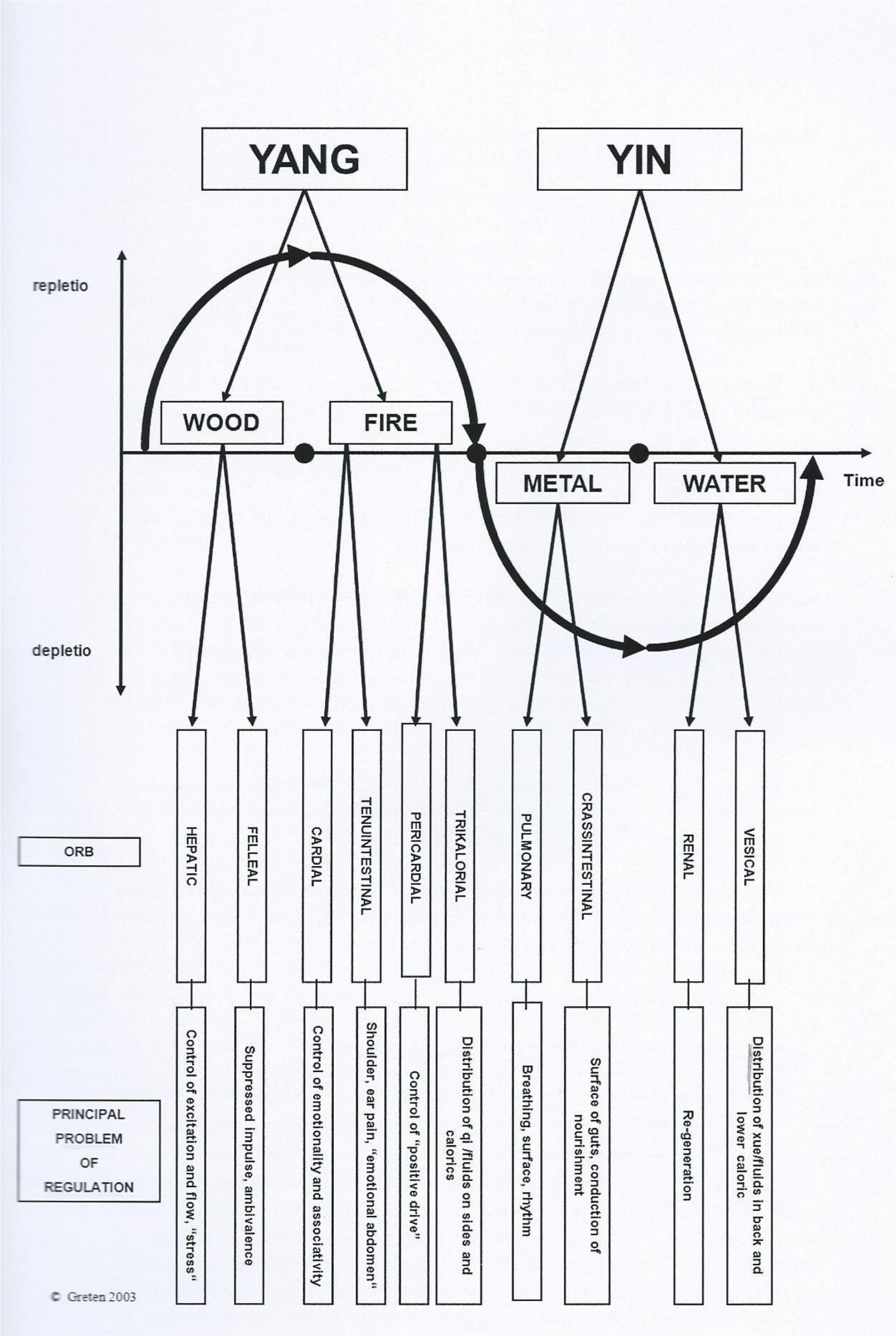


Figure 8: Orbs and principal problems of regulation (Greten, 2007).

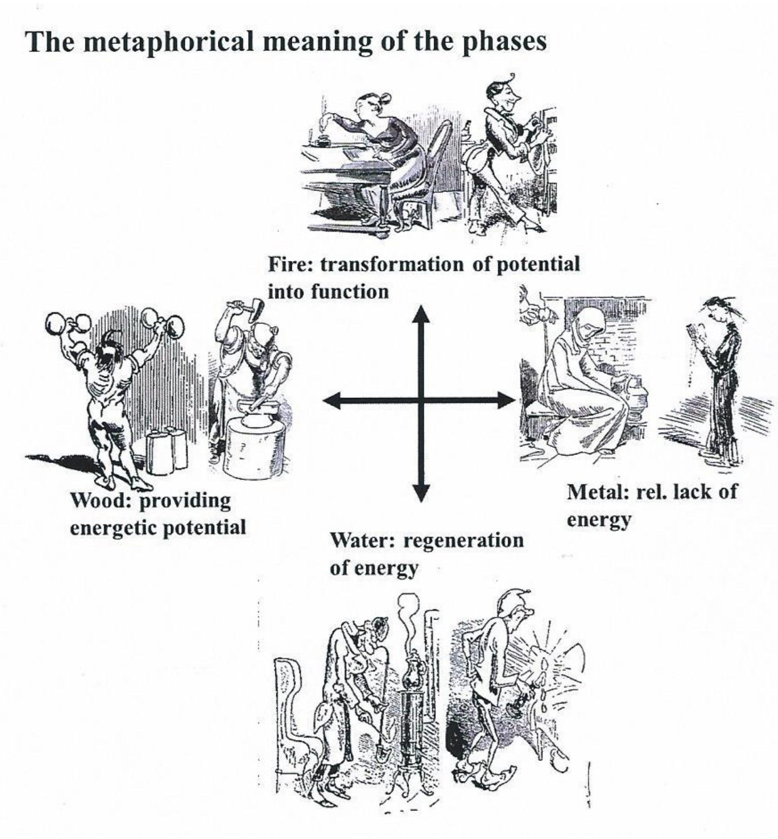


Figure 9: Vegetative functions are the basis of specific behavior.

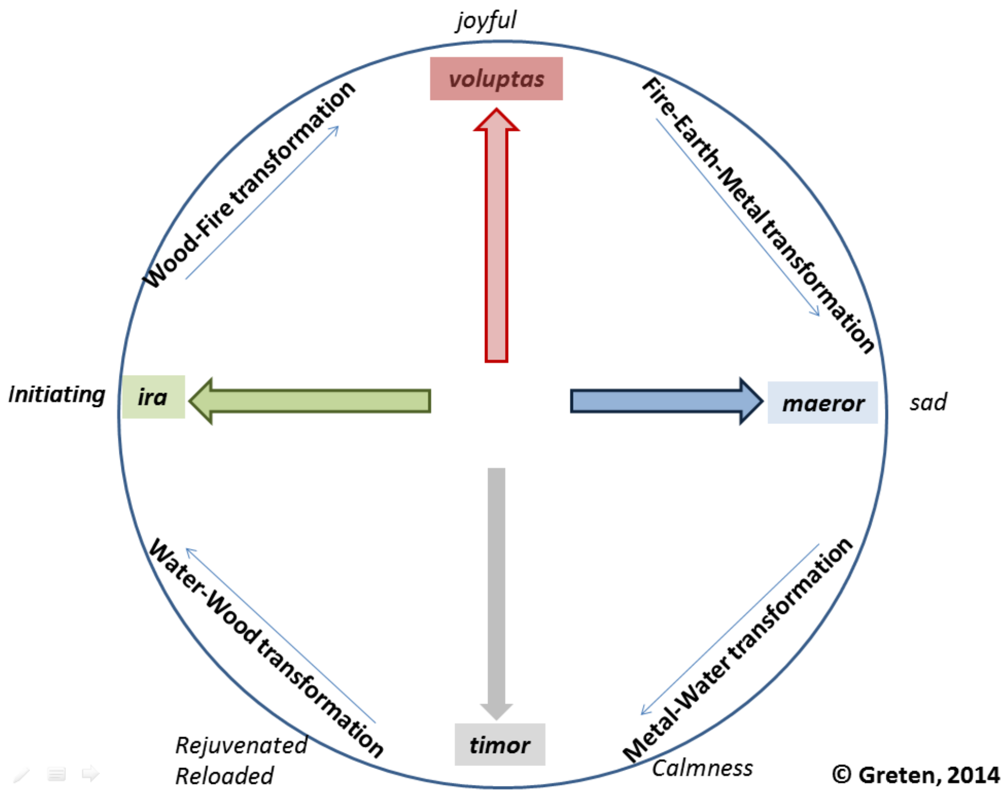


Figure 10: Vectorial representation of e-motions.

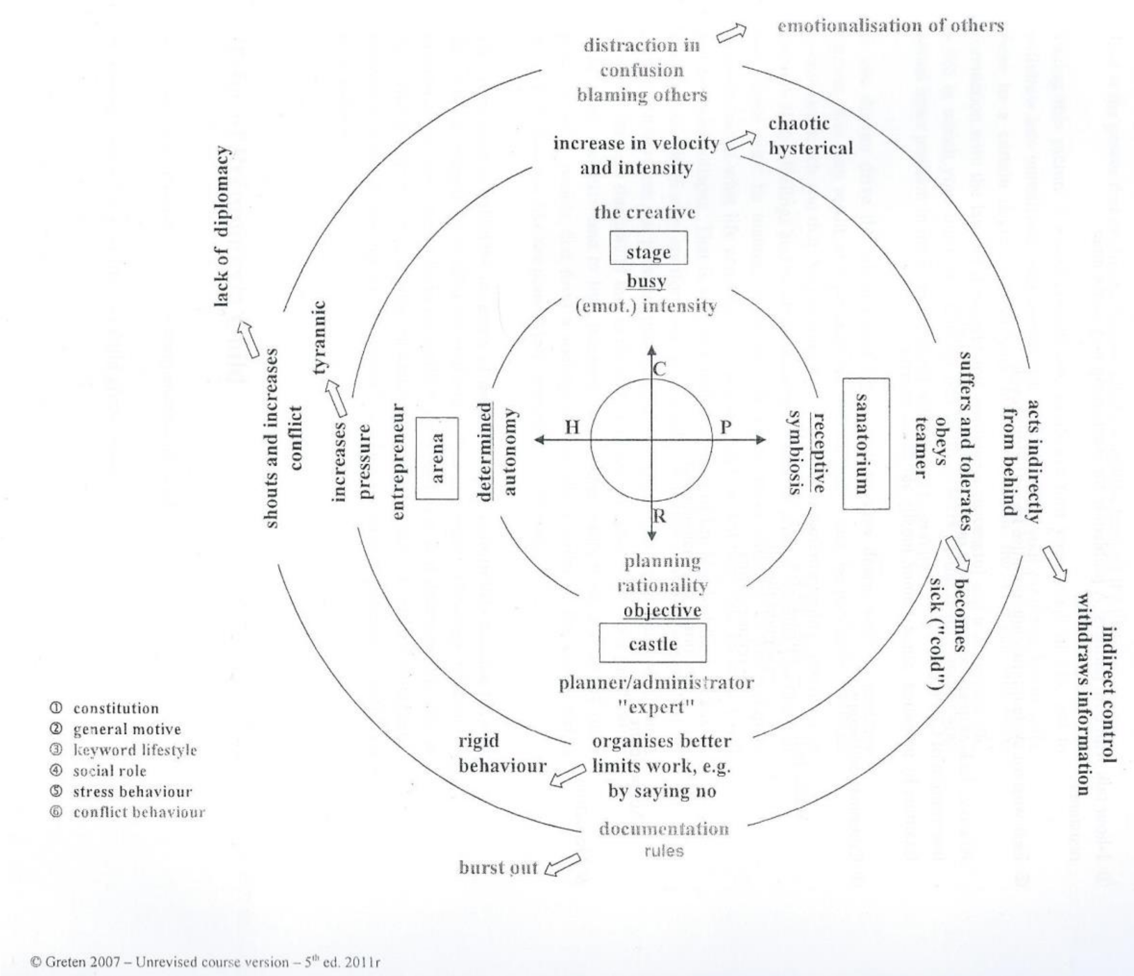


Figure 11: Lifestyles according to the phases (Greten, 2007).

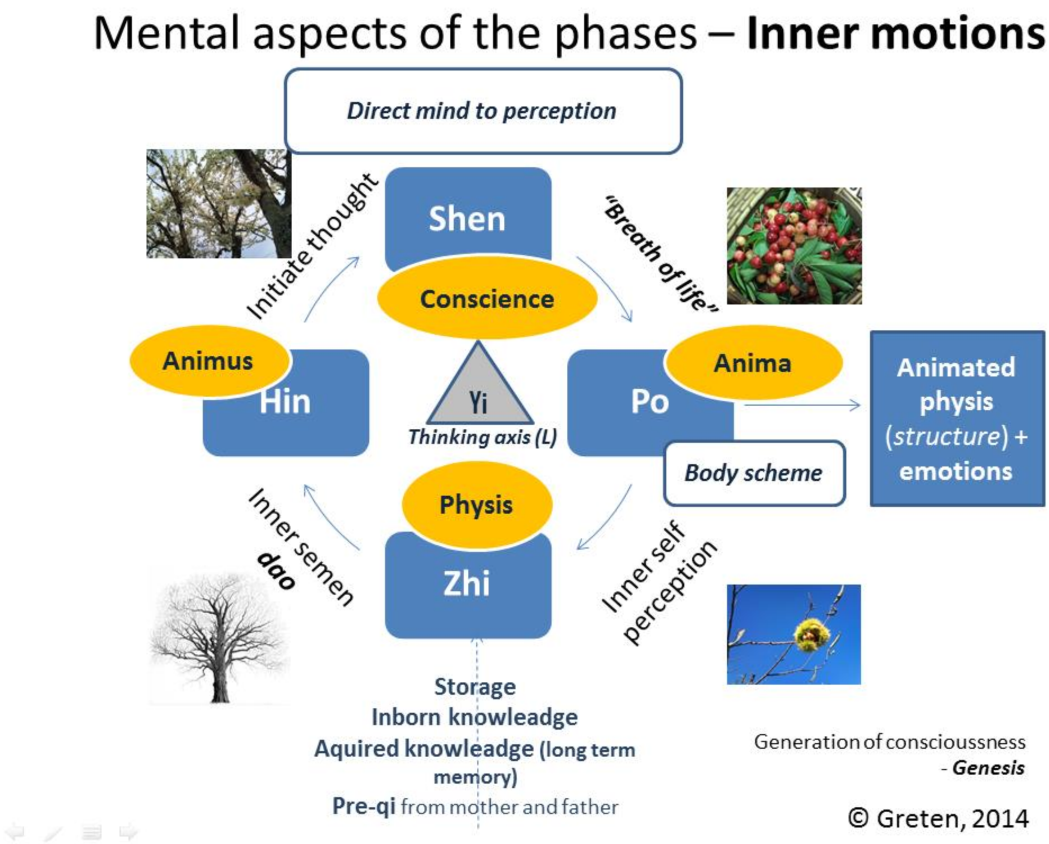


Figure 12: Mental aspects of the phases – Inner Motions.

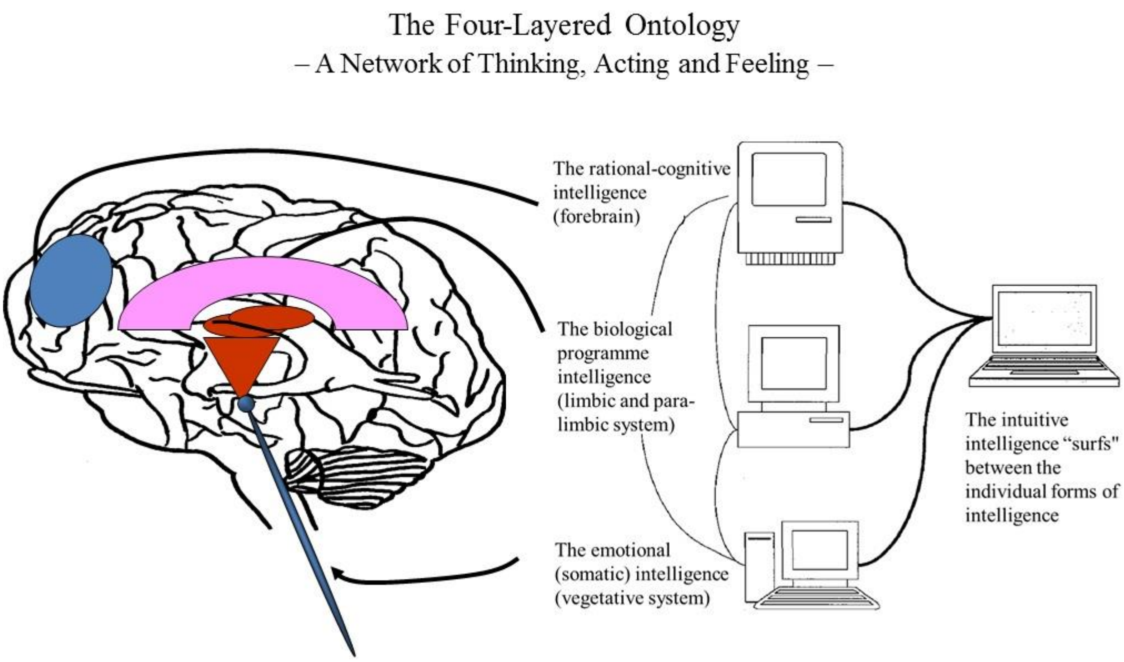


Figure 13: The Four-Layered Ontology – a Network of Thinking, Acting and Feeling (Greten, 2007).

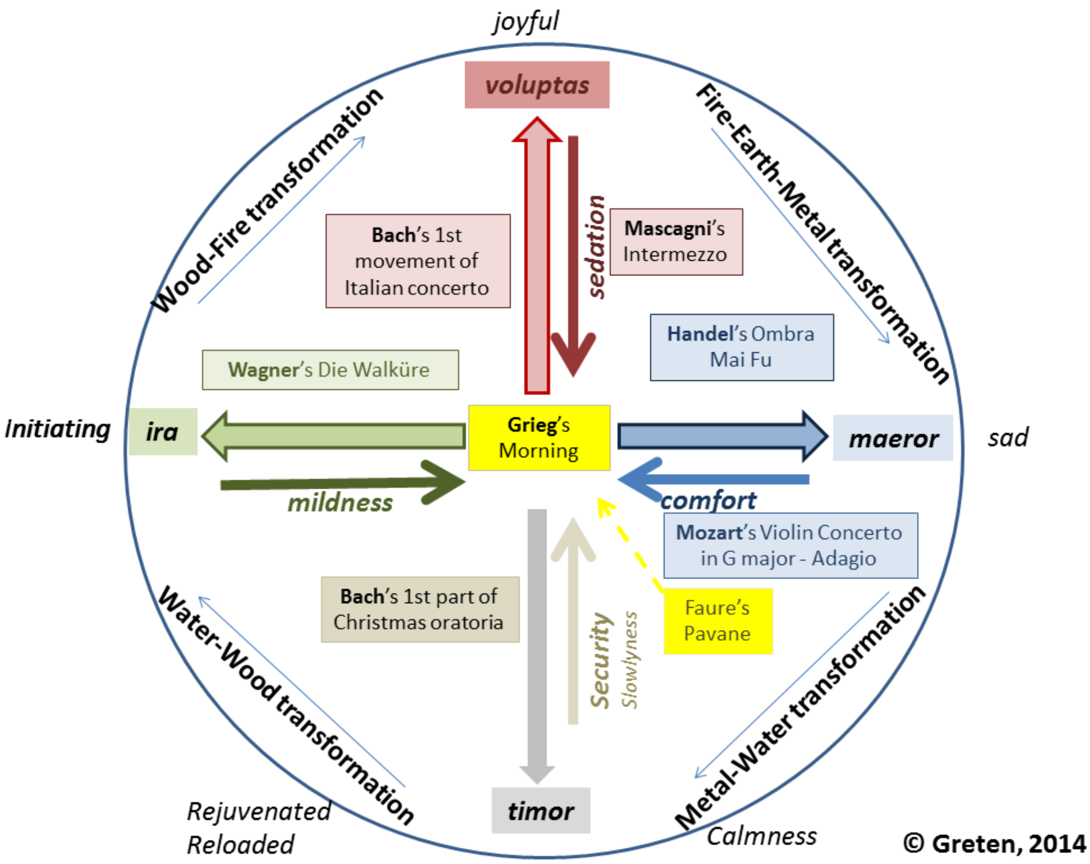


Figure 14: First hypothetic allocation of music pieces.

Table 2: First hypothetic allocation of music pieces.

Composer	Music piece	Phase or Therapeutic vector
R. Wagner	*Die Walküre* - Ride of the Valkyries	Wood
J. S. Bach	1st movement of Italian concerto	Fire
Pietro Mascagni	Intermezzo – Cavalleria Rusticana	Fire
Eduard H. Grieg	Peer Gynt Suite No. 1 – *Morning Mood*	Earth (S)
Handel	Ombra mai fu	Metal
Mozart	Violin Concerto in G major – Adagio	Metal
G. Faure	Pavane	Earth
J. S. Bach	*Weihnachts-Oratorium* - 1st part of Christmas oratoria	Water

➢ *TMMS*-24

INSTRUÇÕES

Neste questionário encontrará algumas afirmações sobre as suas emoções e sentimentos.

Leia atentamente cada frase e indique, por favor, o grau em que está de acordo ou desacordo com cada uma delas marcando com **X** o número que mais se aproxima das suas preferências.

Tenha sempre presente que não há respostas certas ou erradas, nem respostas boas ou más. Não gaste muito tempo a pensar em cada resposta.

1	2	3	4	5
Discordo totalmente	Discordo em parte	Nem concordo nem discordo	Concordo em parte	Concordo plenamente

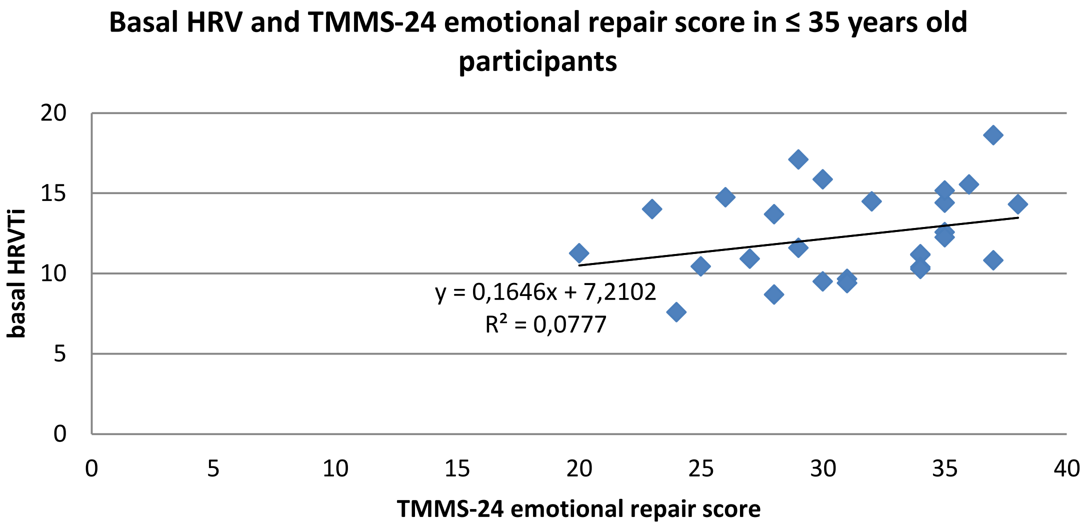
1.	Presto muita atenção aos meus sentimentos.	1	2	3	4	5
2.	Preocupo-me muito com os meus sentimentos.	1	2	3	4	5
3.	Acho que é útil pensar nas minhas emoções.	1	2	3	4	5
4.	Vale a pena prestar atenção às minhas emoções e estados de espírito.	1	2	3	4	5
5.	Deixo que os meus sentimentos se intrometam com os meus pensamentos.	1	2	3	4	5
6.	Penso constantemente no meu estado de espírito.	1	2	3	4	5
7.	Penso muitas vezes nos meus sentimentos.	1	2	3	4	5
8.	Presto muita atenção àquilo que sinto.	1	2	3	4	5
9.	Normalmente sei o que estou a sentir.	1	2	3	4	5
10.	Muitas vezes consigo saber aquilo que sinto.	1	2	3	4	5
11.	Quase sempre sei exactamente aquilo que sinto.	1	2	3	4	5
12.	Normalmente conheço os meus sentimentos sobre as pessoas ou qualquer assunto.	1	2	3	4	5
13.	Tenho, muitas vezes, consciência do que sinto sobre qualquer assunto.	1	2	3	4	5
14.	Consigo dizer sempre o que sinto.	1	2	3	4	5
15.	Às vezes, consigo dizer o que sinto.	1	2	3	4	5
16.	Consigo perceber aquilo que sinto.	1	2	3	4	5
17.	Embora, por vezes, esteja triste tenho, quase sempre, uma atitude optimista.	1	2	3	4	5
18.	Mesmo que me sinta mal, tento pensar em coisas agradáveis.	1	2	3	4	5
19.	Quando me aborreço, penso nas coisas agradáveis da vida.	1	2	3	4	5
20.	Tento ter pensamentos positivos mesmo que me sinta mal.	1	2	3	4	5
21.	Se sinto que estou a perder a cabeça, tento acalmar-me.	1	2	3	4	5
22.	Preocupo-me em manter um bom estado de espírito.	1	2	3	4	5
23.	Tenho sempre muita energia quando estou feliz.	1	2	3	4	5
24.	Quando estou zangado procuro mudar a minha disposição.	1	2	3	4	5

Document 1: Trait Meta-Mood Scale-24.

Table 3: TMMS-24 and its subcomponents medium and median score by sex.

	Female	Male	Total
Age	35,97 35	32,5 30	34,86 33
Attention	30,87 32	29 28,5	30,27 31
Clarity	30,17 30,5	27,64 29	29,36 30
Repair	30,7 31,5	30,43 30,5	30,61 31
TMMS-24 total score	91,73 91,5	87,07 89	90,25 91

Legend: Media; Median



Graphic 1: Correlation between basal HRV and TMMS-24 emotional repair score in ≤35 years old participants

Table 4: Basal HRV Ti and TMMS-24 mood repair score by age groups.

	≤35 years old	>35 years old
Basal HRV Ti	12,31 11,42	8,45 7,35
TMMS-24 mood repair	31 31	29,94 31

Legend: Media; Median

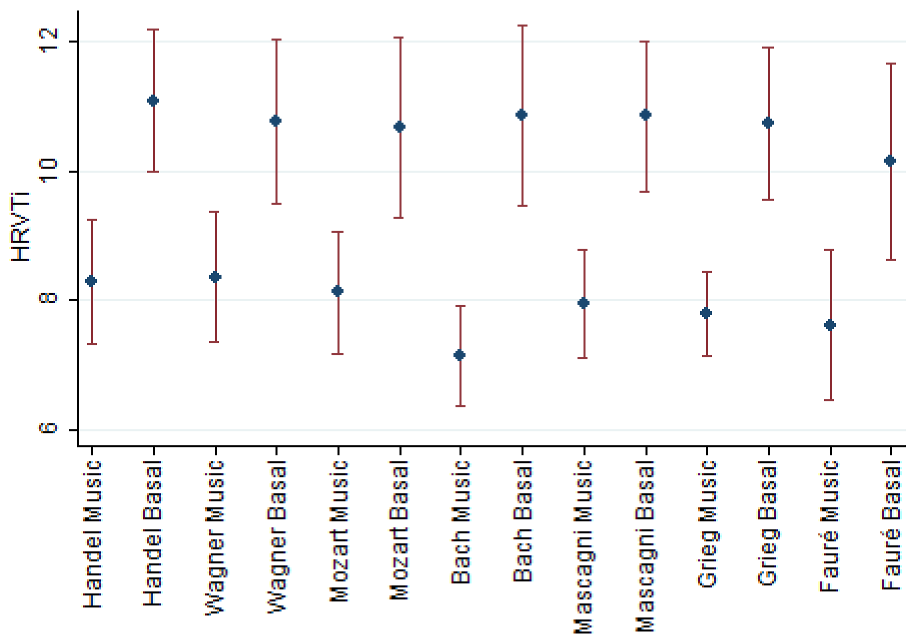
Table 5: Basal HRVTi and age (logistic regression, p<0,05).

basal_hrvti	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.2188088	.0438343	-4.99	0.000	-.3072092	-.1304085
const	18.57057	1.581158	11.74	0.000	15.38186	21.75928

Table 6: Basal HRVTi and HRVTi during music pieces.

Music	N	Media HRVTi music	Media HRVTi basal	Difference	CI 95% music	CI 95% basal
Handel	41	8,288178	11,07525	-2,787076	7,328441 9,247915	9,984755 12,16575
Wagner	44	8,366738	10,75426	**-2,387524**	7,361923 9,371553	9,496037 12,01249
Mozart	31	8,128898	10,66758	-2,53868	7,190977 9,066819	9,27318 12,06198
Bach	37	7,15871	10,85726	**-3,698546**	6,386739 7,930681	9,468585 12,24593
Mascagni	38	7,948045	10,83681	-2,888764	7,120231 8,775859	9,680527 11,99309
Grieg	40	7,800647	10,72212	-2,921476	7,144491 8,456803	9,544588 11,89966
Fauré	22	7,624959	10,14704	-2,522082	6,470681 8,779238	8,636079 11,658

Media basal HRVTi N=45: 10,98



Graphic 2: HRVTi media values during different music auditory stimulation and basal HRVTi (95% confidence interval).

Table 7: Basal SDNN and SDNN during music pieces.

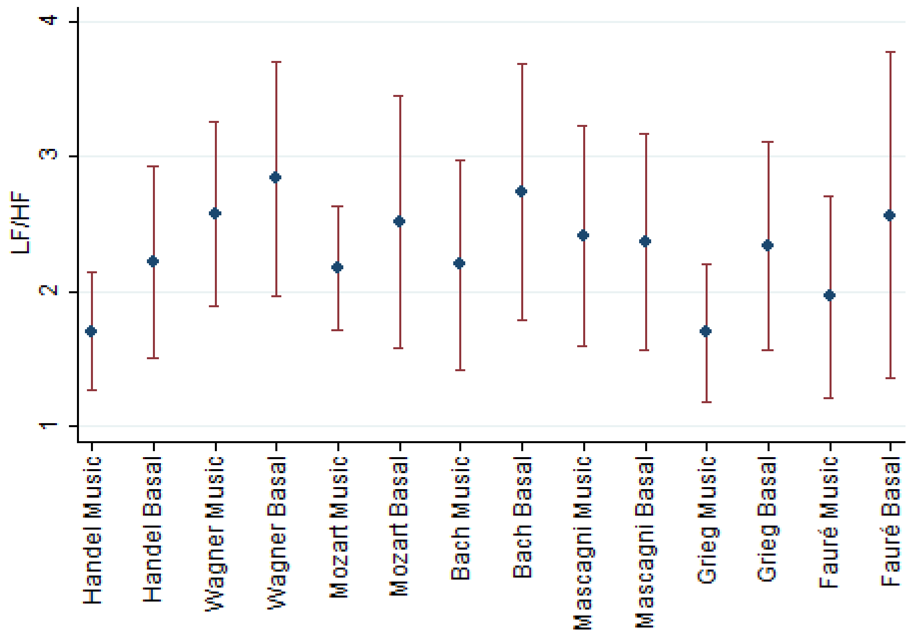
Music	N	Media SDNN music	Media SDNN basal	Difference	CI 95% music	CI 95% basal
Handel	41	45,41192	64,56788	-19,15596	37,96434 52,85949	38,0061 91,12966
Wagner	44	46,1392	50,16904	-4,029844	38,19034 54,08805	42,91838 57,4197
Mozart	31	40,7551	47,32508	-6,569978	34,16955 47,34065	40,78615 53,864
Bach	37	36,25396	63,91249	**-27,65854**	30,47567 42,03225	30,38198 97,44301
Mascagni	38	45,54026	62,56084	-17,02058	37,25608 53,82445	35,24076 89,88092
Grieg	40	47,13149	50,16693	-3,03544	27,25424 67,00875	43,32388 57,00999
Fauré	22	37,98209	47,08852	-9,106428	29,78987 46,17431	38,66723 55,5098

SDNN media N= 45: 62,03

Table 8: Basal LF/HF and LF/HF during music pieces.

Music	N	Media LF/HF music	Media LF/HF basal	Difference	CI 95% music	CI 95% basal
Handel	41	1,703339	2,223912	-0,5205737	1,264727 2,141951	1,513955 2,93387
Wagner	44	2,570009	2,836252	**-0,2662433**	1,886729 3,253289	1,969061 3,703444
Mozart	31	2,175768	2,510406	-0,3346377	1,721068 2,630468	1,577014 3,443798
Bach	37	2,200032	2,735567	-0,5355351	1,419904 2,98016	1,788307 3,682827
Mascagni	38	2,411917	2,368323	**0,0435941**	1,59357 3,230264	1,56442 3,172226
Grieg	40	1,697362	2,333564	**-0,6362024***	1,184594 2,21013	1,564562 3,102567
Fauré	22	1,961016	2,56239	**-0,6013741**	1,210943 2,711089	1,356208 3,768572

Media LF/HF N=45: 2,35; *p<0,05

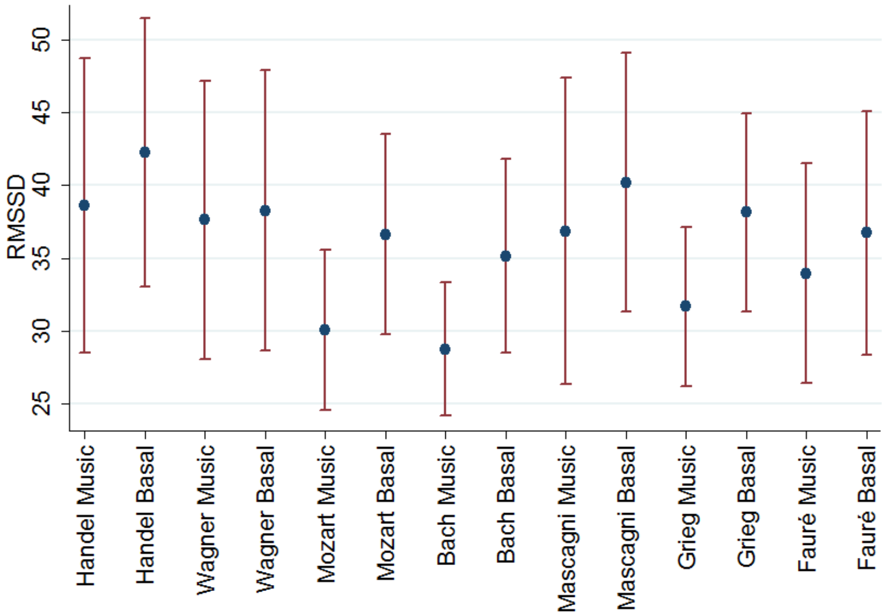


Graphic 3: LF/HF media values during different music auditory stimulation and basal LF/HF (95% confidence interval).

Table 9: Basal RMSSD and RMSSD during music pieces

Music	N	Media RMSSD music	Media RMSSD basal	Difference	CI 95% music	CI 95% basal
Handel	41	38,60605	42,25211	**-3,646053***	28,48378 48,72832	33,04084 51,46337
Wagner	44	37,63382	38,26235	-0,6285294	28,08459 47,18306	28,62526 47,89945
Mozart	31	30,06258	36,63839	**-6,575806***	24,5331 35,59203	29,76367 43,5131
Bach	37	28,759	35,162	**-6,403***	24,18322 33,33478	28,48541 41,83859
Mascagni	38	35,87622	40,22243	-3,346216	26,36211 47,39032	31,30794 49,13693
Grieg	40	31,68436	38,14333	**-6,458974***	31,30161 44,98506	26,21311 37,1556
Fauré	22	33,95545	36,73455	-2,779091	26,40621 41,5047	28,33622 45,13287

Media RMSSD N=45: 41,18477; *p<0,05



Graphic 4: RMSSD media values during different music auditory stimulation and basal RMSSD (95% confidence interval).

Table 10: Respiratory rate during different music pieces.

Respiratory rate (cpm)	**Handel**	**Wagner**	**Mozart**	**Bach**	**Mascagni**	**Grieg**	**Fauré**
Media	17,4	**18,1**	16,6	16,7	17,2	16,6	**14,5**
Median	18,3	18,1	16,6	16,9	17,2	16,7	13,9

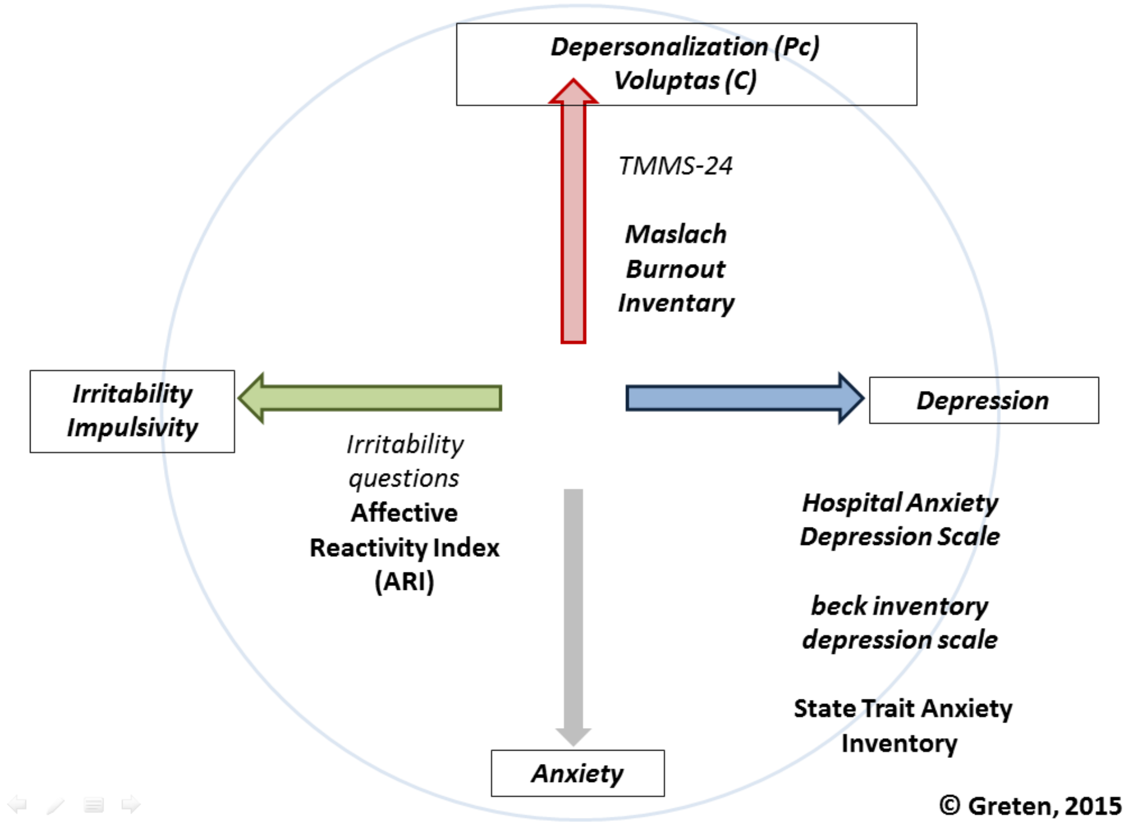
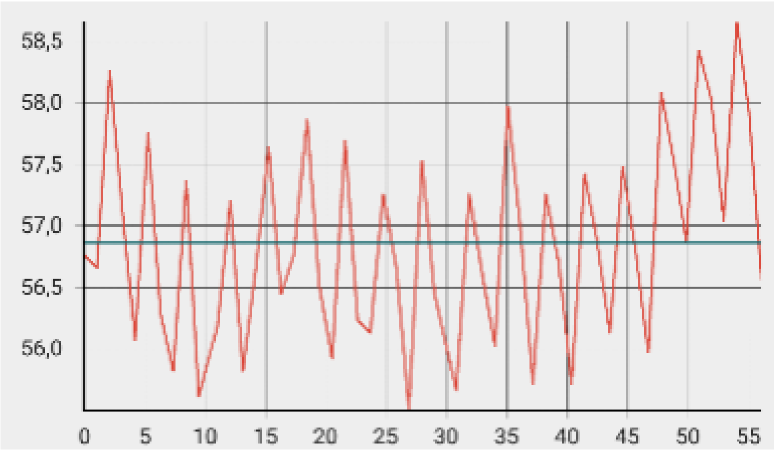


Figure 15: Scales to more accurate characterize emotional vegetative status.

Table 11: HRV parameters (Clinical case).

	SDNN	RMSSD	HRV Ti	LF/HF
Basal	**1351,14**	**1925,46**	8,24	0,52
M1 – Mascagni	19,18	19,93	5	0,27
M2 – Grieg	15,37	22,9	5,9	0,18
M3 – Handel	14,86	22,04	4,42	0,17
M4 – Mozart	14,01	20,7	5,08	0,16

Graphic 5: Heart rate (bpm) through time (seconds) during the 3 minute basal evaluation (Clinical Case). CardioMood, 2015.



Graphic 6: Heart rate (bpm) through time (seconds) during Handel music auditory stimulation (Clinical Case). CardioMood, 2015.